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CONTRACT TRIAL OF THE UNITED STATES BATTLESHIP *KENTUCKY.*

BY COMMANDER HARRIE WEBSTER, U. S. NAVY.

The battleship *Kentucky* is a twin-screw, armored, seagoing battleship, 368 feet between perpendiculars, 72 feet 2½ inches beam, and of 11,600 tons displacement at a load draught of 23 feet 7⅞ inches. She was constructed by the Newport News Shipbuilding and Dry Dock Company, Newport News, Va., under contract of January 2d, 1896.

The hull and machinery specifications were supplied by the Navy Department, but the few changes and modifications found necessary as the work of construction progressed were developed by the contractors.

The cost of the *Kentucky* was limited by law to $2,250,000, with a time allowance for completion of three years. This contract price, however, did not include armor or armament, neither does it include ordnance nor ordnance outfits.

A speed of sixteen knots an hour for four consecutive hours over an open sea course was guaranted by the contractors, but

no premium for any excess over that speed was included in the contract. On the other hand, a penalty at a rate of $100,000 per knot was to be imposed in case the speed failed of the required sixteen knots per hour, and the right to wholly reject the ship or accept her at a lower price was reserved in case the speed fell below fifteen knots per hour.

The weight of all machinery was allowed to reach 1,100 tons of 2,240 pounds, any excess up to 5 per cent. of this limit involving a penalty of $500 per ton, and if over 5 per cent. an additional lump penaltyof $10,000 was fixed.

The hull is divided into two hundred and ninety-two watertight compartments, and is built of mild steel of American manufacture. All the wood employed in the interior fittings is fire proofed, but wood is only used where absolutely necessary, and in this respect the *Kentucky* will bear favorable comparison with any ship of her class afloat.

HULL DATA.

Length between perpendiculars, feet	368
on L.W.L., feet and inches	368- 1⅛
over all (including rudder), feet and inches	375- 4½
Beam, extreme, feet and inches	72- 2½
at L.W.L., feet and inches	72- 2½
Ratio of length to beam	5.20
Depth, from top of main-deck beams at side to bottom of frames at M.P., feet and inches	33- 8
Height of superstructure above main-deck beams to top of hammock berthing on upper deck, feet and inches	12- 0
Draught, normal, forward, feet and inches	23- 7⅜
aft, feet and inches	23- 7⅜
mean, feet and inches	23- 7⅜
Displacement, corresponding to normal draught, tons	11,600
per inch, at L.W.L., tons	47.74
Area of immersed midship section to L.W.L., square feet	1,620
L.W.L. plane, square feet	20,070
Center of gravity of L.W.L. plane, aft of M.P., feet and inches	1- 9
buoyancy above bottom of keel, feet and inches	12- 9⅝
forward of M.P., feet and inches	1- 0½
gravity above bottom of keel, feet and inches	25- 0½
Transverse metacenter above center of buoyancy, feet and inches	16-11¼
Longitudinal metacenter above center of buoyancy, feet and inches	367- 0
Coefficient of fineness on extreme dimensions	.643

Coefficient of fineness of midship section	.957
Coefficient of fineness of L.W.L.	.757
Cylindrical coefficient	.681
Number of frames	94
watertight compartments	292

The general data of the *Kentucky*, outside of performance, is similar to that of the *Kearsarge*, which was published in the last number of the JOURNAL, but for convenience of reference the principal ones will be repeated here.

Armor and Armament.—The side belt is of Harveyized nickel-steel extending 3 feet 6 inches above and 4 feet below the 23½-foot load line. The thickness amidships of the side belt is 16½ inches at lower edge of chamfer at the top of the armor, tapering to 9½ inches at bottom. The maximum thickness of armor at the water line is maintained from the center line of the after barbettes, where the belt begins, to the forward coal-bunker bulkhead, tapering to 10½ inches to the center line of forward barbettes, thence to 4 inches in a distance of 30 feet, which thickness is then maintained to the bow of the vessel. The triangular armor extends from the slopes of the protective deck to the top of the armor belt at the forward and after ends of the machinery spaces, the forward bulkhead being 10 inches and the after bulkhead 12 inches in thickness. Above the side belt there is a casemate 6 inches thick made up of two ½-inch plates and one 5-inch plate; the athwartship bulkheads are 4 inches thick, and are worked from the sides of the vessel to the centers of the barbettes. The thickness of the superstructure armor is 6 inches. The protective deck between armor bulkheads is 2¾ inches thick, and at the extremities on side slopes are fitted plates of armor 4 inches thick. The splinter bulkheads between 5-inch gun stations are each one piece of plate, 80 pounds per square foot.

The barbettes are 15 inches thick at the front and 12½ inches thick at the rear; the 13-inch turrets are 17 inches thick at the front and 15 inches thick at the rear; the 8-inch turrets are 11 inches thick at the front and 9 inches thick at the rear. The conning tower is elliptical in shape, and is 10 inches thick. An armor tube 7 inches thick is fitted between the base of the conning tower and the protective deck, to afford protection to the

voice pipes, electric wires, engine telegraphs, steering gear and engine tell-tales.

The main battery consists of four 13-inch breech-loading rifles, 35 calibers, mounted in pairs, in two balanced turrets, on the fore-and-aft center line of the ship, on the main deck; four 8-inch breech-loading rifles, 40 calibers, mounted in pairs, in two turrets superposed on the 13-inch turrets; and fourteen 5-inch rapid-fire breech-loading rifles, 40 calibers, mounted in broadside, on the main deck within the superstructure.

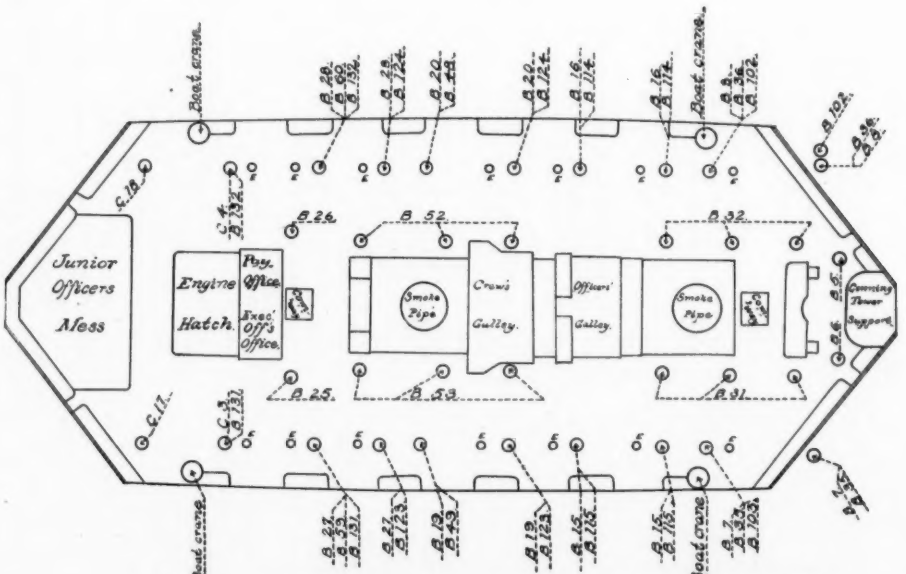
The secondary battery consists of twenty 6-pounder rapid-fire guns, eight 1-pounder rapid-fire guns, four of which are automatic, four Colt automatic machine guns, and two 3-inch field guns. There are four tubes for Whitehead torpedoes, two on each side, discharging directly from the berth deck. The turrets are trained by electricity, and the 13-inch guns are elevated and loaded by the same power. The 5-inch guns are worked by hand on central-pivot carriages.

Coal Bunkers.—There are 34 coal bunkers which can be filled either from the upper or main deck by means of admirably arranged portable chutes and trunks. Trolley gear is provided for coal transportation between bunkers and steam fire-extinguishing apparatus is installed in all bunkers.

Main Engines.—The motive power consists of two three-cylinder triple-expansion engines of the inverted vertical direct-acting type, located in two watertight compartments on opposite sides of the ship, the high-pressure cylinders being placed forward in both cases.

The engine framing is of wrought steel, and the main steam valves are of the single-ported piston type, operated by the well-known Stephenson link. The valve gears of the three cylinders are mutually interchangeable, and the cut-offs are arranged for an expansion of from one-half to seven-tenths of the stroke.

The main piston rods are of forged nickel-steel, hollow and oil tempered, the outside diameter being $7\frac{1}{2}$ inches, the central hole being $3\frac{1}{2}$ inches in diameter. The connecting rods are also hollow and of nickel-steel. The eccentrics are of cast iron, while the eccentric straps are of brass.



Coaling holes on Main-deck and Forecastle with Nos. of Bunkers to which they lead.

"U. S. S. Kentucky."

BUNKER LIST.

Compartment.		Capacity.	
		Cubic feet.	Tons.
B– 5		2,031	47.23
B– 6		1,781	41.42
B– 7		4,675	108.72
B– 8		4,675	108.72
B–15		3,598	83.68
B–16		3,598	83.68
B–19		3,717	86.44
B–20		3,717	86.44
B–27		3,707	86.21
B–28		3,707	86.21
B–25		3,214	74.74
B–26		2,895	67.32
C– 3		1,484	34.51
C– 4		1,484	34.51
Total.....	14	44,283	1,029.83
SPLINTER DECK.			
B–31		1,584	36.84
B–32		1,584	36.84
B–35		1,151	26.77
B–36		1,151	26.77
B–53		1,673	38.90
B–52		1,693	39.37
B–48		596	13.86
B–49		596	13.86
B–59		601	13.98
B–60		601	13.98
C–17		612	14.23
C–18		612	14.23
Total.....	12	12,454	289.63
BERTH DECK.			
B–102		1,103	25.65
B–103		714	16.61
B–114		1,700	39.53
B–115		1,700	39.53
B–123		1,727	40.16
B–124		1,727	40.16
B–131		1,510	35.12
B–132		1,516	35.26
Total.....	8	11,697	272.02
Total ship.....	34	68,434	1,591.48

The crank shafts are of steel, forged, 14$\frac{3}{4}$ inches diameter, and are in three interchangeable and reversible sections. They are hollow bored, the axial holes being 7$\frac{1}{2}$ inches in diameter. The

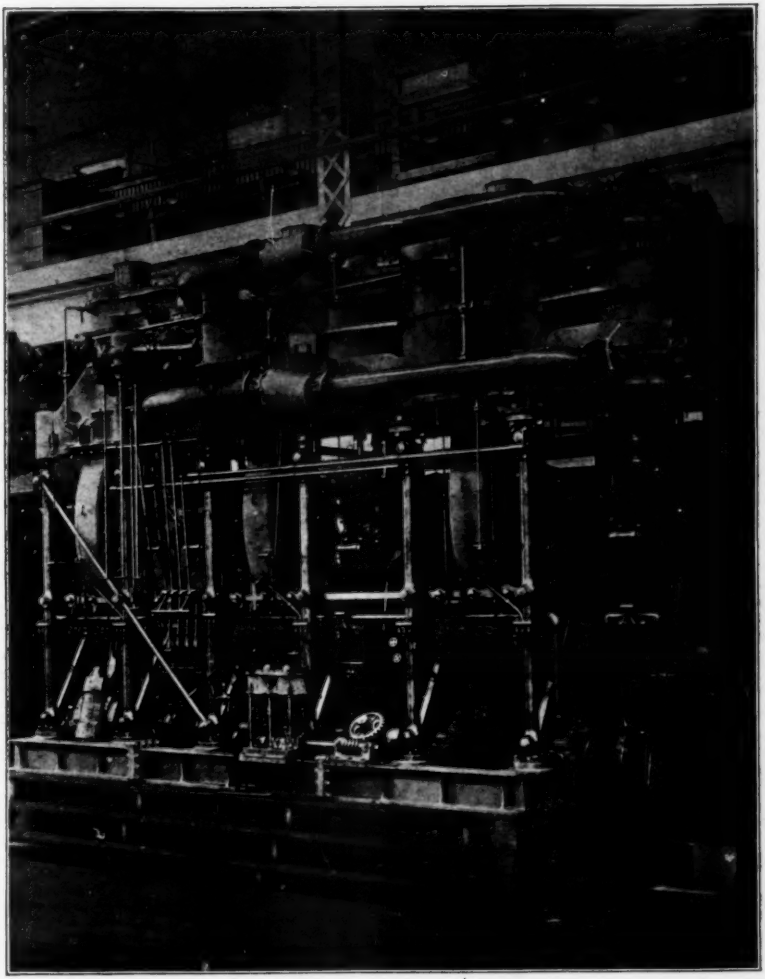
thrust bearings are of the ordinary horseshoe pattern, each having eleven collars faced with white metal. The cranks are placed 120 degrees apart.

ENGINE DATA.

Cylinders, number for each engine	3
H.P., diameter, inches	33½
I.P., diameter, inches	51
L.P., diameter, inches	78
Stroke of pistons, inches	48
Valves, H.P. (one for each cylinder), diameter, inches	19½
I.P. (two for each cylinder), diameter, inches	18
L.P. (four for each cylinder), diameter, inches	18
Balance pistons, H.P., diameter, inches	6
I.P., diameter, inches	7½
L.P., diameter, inches	7½
Valve stems, diameter, inches	2¾
diameter, through valve, inches	1⅞
Main steam pipe (13 inches diameter) area cross section, square inches	132.73
Exhaust pipes to I.P. cylinder (1) 17 inches H.P. end, 17 inches I.P. end, area of cross section, square inches	226.86
L.P. cylinder (4) 15 inches I.P. end, (8) 11 inches L.P. end, area of cross section, square inches	706.50 759.88
condenser, (2) 19 inches diameter, area of combined cross section, square inches	566.77
Volume swept by H.P. piston (mean), per stroke, cubic feet	23.84
I.P. piston (mean), per stroke, cubic feet	56.09
L.P. piston (mean), per stroke, cubic feet	132.04
Net area of I.P. to H.P. piston	2.34
L.P to I.P. piston	2.36
Net area of L.P. to H.P. piston	5.53
Clearances of H.P. cylinders, per cent.....top, 18.9; bottom,	22.8
I.P. cylinders, per cent.....top, 18.9; bottom,	24.7
L.P. cylinders, per cent.....top, 17.5; bottom,	22.9
Piston rods, diameter, inches	7½
length from piston to crosshead, feet and inches	6– 6⅛
Connecting rods, length from center to center, feet	8
diameter of upper end, inches	7⅞
diameter of lower end, inches	8¼
crossheads bolts (2), diameter, inches	4¼
crank-pin bolts (2), diameter, inches	4¼
Crossheads, surface (ahead), square inches	459
(backing), square inches	357
pins, diameter, inches	9⅜
length, inches	14

Reversing gear, steam cylinder, diameter, inches	15
controlling cylinder, diameter, inches	7½
Crank shafts, diameter, inches	14¾
axial hole, inches	7½
coupling discs, diameter, inches	29
thickness, inches	3½
bolts in one flange (6), diameter, inches	3½
journals, diameter, inches	14¾
length, inches	16½
length of each section, feet and inches	8–10
Crank pins, diameter, inches	14¾
length, inches	17
axial hole, inches	7½
Crank webs, width, inches	16½
thickness, inches	10
Thrust shaft, diameter, inches	14
diameter of coupling disc, inches	29
axial hole, inches	9
collars, number each shaft	11
diameter, inches	21½
thickness, inches	2
distance between, inches	3½
surface, total for both engines, square inches	4,600.64
length, feet and inches	15– 5½
Line shafts, diameter, inches	14
axial hole, inches	9
diameter of coupling discs, inches	29
length, feet and inches	31–10⅛
Propeller shafts, diameter, inches	14¾
axial hole, inches	9¾
Propeller shafts, outboard, length, feet and inches	26– 5½
Propeller shafts, outboard, coupling, diameter, inches	21
length, feet and inches	4– 8½
inboard, length, feet and inches	31–10
Stern bracket bearing, length, inches	48½
diameter, inches	16⅛
tube bearing, length, forward, inches	40¾
aft, inches	42

Main Condensers.—Each main engine has a separate condenser, the shell proper of which is of wrought steel, the water chests being of composition. Otherwise the usual method of construction is followed, the circulating water first passing through the lower tubes and returning through the upper nests.



SHOWING GENERAL CONSTRUCTION OF MAIN ENGINE.

CONDENSER DATA.

Diameter of shell (inside), feet and inches	5- 8½
Thickness of shell, inch	5/16
Length over heads, feet and inches	13- 4
Tubes, diameter (outside), inch	⅝
length between tube sheets, feet and inches	11- 6
thickness, No. 18 B.W.G., inch	.049
number in each condenser	3,749
Cooling surface, each condenser, square feet	7,050
Total cooling surface, square feet	14,100
Ratio of total cooling to total heating surface	1 to 1.56

Air and Circulating Pumps.—There is a separate air and separate circulating pump for each main condenser, the former being of the Worthington vertical, twin-cylinder, single-acting type, and the latter of the usual centrifugal type, commonly used with modern marine machinery.

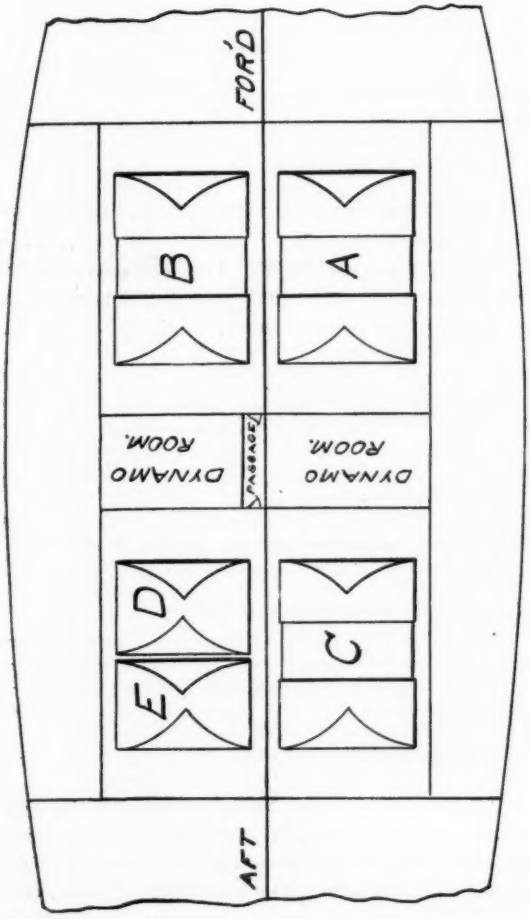
AIR-PUMP DATA.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches	18
Diameter of piston rods, inches	2 7/16
pump rods, inches	2¾
pump valves, inches	3, 4, 4½
Ratio of volume swept by L.P. piston, net area, per stroke, to that of the two air-pump buckets, per stroke	13

CIRCULATING-PUMP DATA.

Diameter of steam cylinders, inches	11
Stroke, inches	8
Diameter of pump runner, inches	42
Width of runner, inches	8½
Diameter of inlet and of outlet nozzle, inches	15½
Rated capacity, each pump, gallons per minute	10,000

Auxiliary Condensers.—There is in each engine room an auxiliary condenser connected with the auxiliary exhaust pipes. The heads and shell are of composition and the tube sheets of rolled brass. Each has a Worthington horizontal, duplex, combined air and circulating pump, the steam cylinders being between the water cylinders and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.



ARRANGEMENT OF BOILERS.

Cooling surface, one condenser, square feet	801
Diameter of steam cylinders, inches	71/2
circulating pump cylinders, inches	81/2
air-pump cylinders, inches	81/2
Stroke, common, inches	10

Feed-Water Heaters.—In each engine room there is a feed-water heater which is similar in construction to a condenser. The auxiliary exhaust pipe has a by-pass valve, so that the exhaust steam may be passed around the tubes of the heater and thence to the condenser. The heaters are located between the feed pumps and the feed main, and the valves are so arranged that the feed water can pass directly to the feed main without passing through the heaters. The heating surface is 496.5 square feet for each heater. The tubes are 1 inch in outside diameter, No. 13 B.W.G. in thickness, and are expanded into the tube sheet. The tubes are tinned inside and out.

Screw Propellers.—These are three-bladed true screws with pitch adjustable to from 16 to 18 feet. The material is manganese bronze thoroughly tinned. The blades are inclined backwards 30 inches from the vertical.

PROPELLER DATA.

Number of blades	3
Diameter, feet and inches	16- 9
of hub, feet and inches	4- 41/2
Length of hub, feet and inches	3- 1
Pitch as set, feet and inches	17- 3
Greatest width of blade, feet	5
Helicoidal area of each screw, square feet	84.2
Projected area, square feet	69.2
Disc area, square feet	220.35
Pitch ÷ diameter	1.03

BOILERS.

The steam-generating plant consists of five steel Scotch boilers placed in four watertight boiler compartments, formed by fore-and-aft and athwartship bulkheads. Two single-ended boilers, back to back, occupy the port after compartment and one double-ended boiler is placed in each of the other three compartments. All boilers are fore-and-aft, so that the fire rooms are athwart-

ships, one at each end of each compartment. There are two cylindrical smoke pipes, 8 feet diameter. The working pressure of all boilers is 180 pounds per square inch.

DOUBLE-ENDED BOILER DATA.

Number double-ended boilers	3
Length, feet	one of 21 and two of 19
Diameter, outside of all, feet and inches	15- 8
Thickness of shell and heads at top, inches	$1\frac{7}{16}$
Combustion chambers, number in each boiler	4
Furnaces, least internal diameter, feet and inches	3- 3
length of grate, feet and inches	6- 7
number in each boiler (corrugated)	8
Tubes, outside diameter, inches	$2\frac{1}{4}$
length between tube sheets, 21-foot boiler, feet and inches	7- $7\frac{3}{8}$
19-foot boilers, feet and inches	6- $7\frac{3}{8}$
number of ordinary, each boiler	816
number of stay, each boiler	332
spaced vertically, inches	$3\frac{1}{4}$
horizontally, inches	$3\frac{1}{4}$
thickness of ordinary, B.W.G.	10
stay, B.W.G.	6
Heating surface, square feet, one 19-foot boiler, tube	4,473
plate	847
each 21-foot boiler, tube	5,150
plate	901
Grate surface, square feet, each boiler	171.2
Steam room, cubic feet, one 19-foot boiler	716.5
each 21-foot boiler	808.5
Smoke pipes (2), diameter, feet and inches	8- 0
area of both, square feet	100.6
height above lowest grates, feet	87
Diameter of boiler main stop valves, inches	$9\frac{1}{2}$
Totals for three double-ended boilers:	
Heating surface, tube, square feet	14,096
plate, square feet	2,595
total, square feet	16,691
Grate surface, square feet	513.6
Ratios:	
Tube H.S. to G.S.	27.44
Plate H.S. to G.S.	5.05
Total H.S. to G.S.	32.40
Area through tubes to G.S.	.139
Volume of furnaces and combustion chambers above grates to G.S.	4.13
Steam room per square foot of G.S.	4.36

Single-Ended Boiler Data.

Number of single-ended boilers	2
Length, feet and inches	9–11½
Diameter, outside, feet and inches	15– 8
Thickness of shell, inches	1 7/16
furnaces, inch	9/16
Combustion chambers, number in each boiler	2
thickness of plates, inch	9/16
depth at top, inches	27½
Furnaces, greatest internal diameter, feet and inches	3– 5⅞
least internal diameter, feet and inches	3– 3
length of grate, feet and inches:	6– 7
number in each boiler corrugated	4
Tubes, outside diameter, inches	2¼
length between tube sheets, feet and inches	6– 6⅜
number of ordinary, each boiler	428
stay, each boiler	164
spaced vertically, inches	3¼
spaced horizontally, inches	3½
thickness of ordinary, B.W.G	10
stay, B.W.G	6
Heating surface, tube, square feet, each boiler	2,280
plate, square feet, each boiler	426.4
total, square feet, each boiler	2,706.4
Grate surface, square feet, each bolier	85.6
Area through tubes, square feet, each boiler	12.42
Steam room, water four inches above highest heating surface, cubic feet	355
Diameter of boiler stop valves, inches	7
Totals for two single-ended boilers:	
Heating surface, tube, square feet	4,560
plate, square feet	852.8
total, square feet	5,412.8
Grate surface, square feet	171.2
Ratios:	
Tube H.S. to G.S.	26.63
Plate H.S. to G.S.	4.92
Total H.S. to G.S.	31.62

All Boilers.

Heating surface, tube, square feet	18,656
plate, square feet	3,447.8
total, square feet	22,103.8
Grate surface, square feet	684.8
Area through tubes, square feet	96.24
Steam room, cubic feet	2,950.5
Area of water surface, square feet	1,032.75

Ratios:

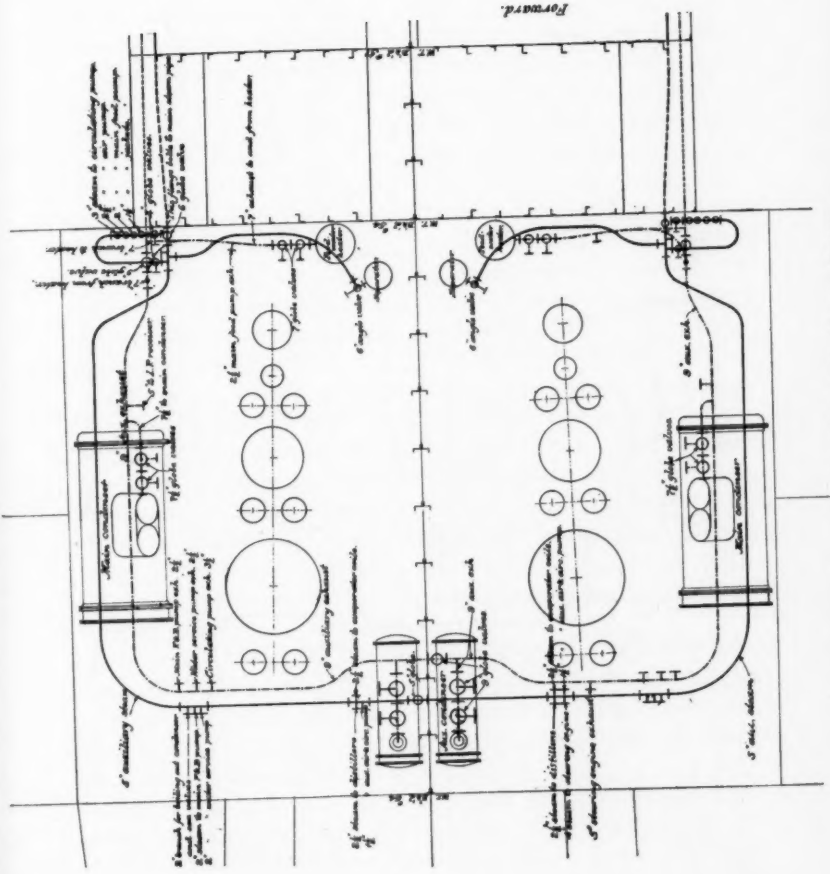
Tube H.S. to G.S.	27.24
Plate H.S. to G.S.	5.03
Total H.S. to G.S.	32.28
Area through tubes to G.S.	.14
Volume of furnaces and combustion chambers above grates to G.S.	4.11
Steam room per square foot of G.S.	4.31

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by eight Sturtevant blowers, one in each fire room. The fans are driven by two-cylinder, vertical, simple, enclosed engines with cranks at 180 degrees.

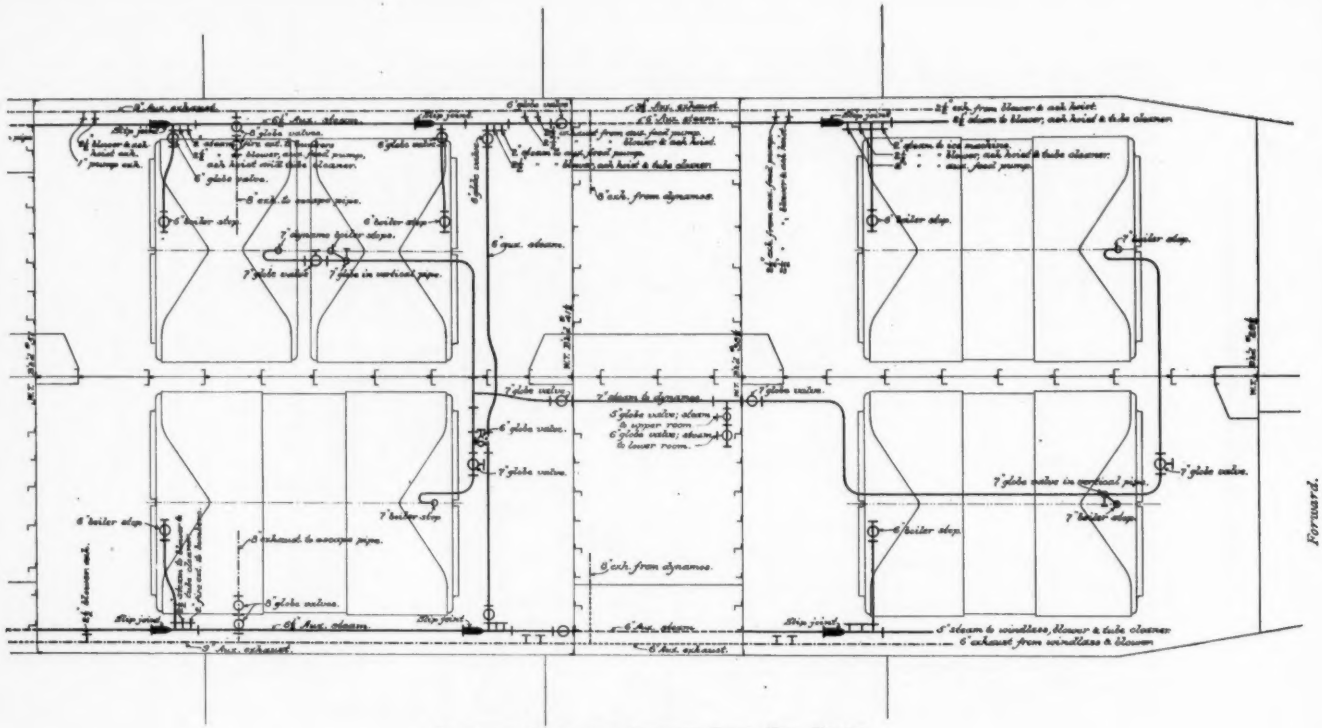
Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan at rim, inches	14
Area of induction nozzle, square inches	1,060.7
eduction nozzle, square inches	2,220

Feed Pumps.—There are two main and four auxiliary feed pumps, all of the Admiralty type, Worthington duplex, and all of the same size, 10 inches by 7 inches by 12 inches, with a capacity of 400 gallons per minute. The main feed pumps are located one in each engine room and draw water from the feed tanks and air-pump suctions and deliver to the boilers; the auxiliary feed pumps draw from the feed tanks, the air-pump suctions, the sea, the drainage system and the boilers, and discharge into the boilers, fire main or overboard. These pumps are located one in each of fire rooms Nos. 3, 4, 5 and 6. The discharges of the main and auxiliary pumps are not connected, the auxiliary feed pumps only feed through the auxiliary feed main. In the port after fire room there is a small duplex Worthington pump, $4\frac{1}{2}$ inches by 3 inches by 4 inches, of 65 gallons per minute capacity, for feeding the auxiliary boilers in port.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex Worthington pump which draws from the sea, the bilge and the drainage system, and delivers into the fire main or outboard. The steam cylinders are 10 and the water cylinders 7 inches in diameter; stroke, 12 inches.



AUXILIARY STEAM AND EXHAUST PIPES, ENGINE ROOMS.


8" Aux. exhaust.
6½" Aux. steam.
Slip joint
6" globe valve.
6" boiler stop.
7" boiler stop.
7" dynamo boiler stops.
7" globe valves.
7" globe valves in vertical pipes.
6" exh. to escape pipe.
6" exh. from dynamos.
6" aux. steam.
7" globe valve.
7" steam to dynamos.
5" globe valve; steam to upper room.
6" globe valve; steam to lower room.
8" exhaust to escape pipe.
5" globe valves.
6½" Aux. steam.
8" Aux. exhaust.
2½" exh. from blower & exh. hoist.
6½" steam to blower; exh. hoist & tube cleaner.
2" steam to sea connections.
2½ " " blower; exh. hoist & tube cleaner.
" " aux. feed pumps.
5" steam to windlass, blower & tube cleaner.
6" exhaust from windlass & blower.
W.T. bhd.
Forward.

AUXILIARY STEAM AND EXHAUST PIPES, FIRE ROOMS.

Water-Service Pumps.—In each engine room there is a vertical, duplex Worthington pump which draws from the sea and delivers into the water-service pipes, the distiller circulating pipes, and into the fire main. These pumps have a capacity of 400 gallons per minute; size, 10 inches by 7 inches by 12 inches.

Bilge and Sanitary Pumps.—There are two single-acting plunger pumps on each main-engine shaft, driven by eccentrics; one pump on each shaft is arranged to draw from the bilge and discharge overboard; the other to draw from the sea and discharge into the flushing main.

Grease Extractors.—A grease extractor is fitted on the discharge of both main feed pumps. It is similar in action to a Macomb strainer; the cartridge is perforated and covered with burlap, through which the water filters. By-pass valves are fitted so that the extractors may be overhauled without interrupting the boiler feed.

Feed Tanks.—There is a feed tank of 2,000 gallons capacity in each engine room. A part of the tank is fitted as a filter, into which the water from their air pumps is delivered. The filter has a movable cover and is provided with sponges. Each tank has a manhole, glass water gage, shut-off and drain cocks. An overflow pipe is fitted and so arranged that any water passing down it may be seen. Each feed-pump suction is provided with a balance valve operated by a float in the feed tank, and so arranged that no air will enter the feed pipes.

Ash Hoists.—In each fire-room hatch there is a Williamson Bros. double, reversible ash hoist, by means of which one bucket of ashes of 300 pounds (with a steam pressure of 80 pounds) can be hoisted in five seconds. The steam cylinders are $4\frac{1}{2}$ inches in diameter, with a stroke of $4\frac{1}{2}$ inches.

Engineer's Workshop.—The workshop is situated on the splinter deck, just forward of the engine rooms. It is fitted with a vertical engine, 7 inches by 7 inches, a 24-inch lathe, a 14-inch screw-cutting lathe, a shaping machine, a double-geared drilling machine, a hand drill press, combined punch and shears, and emery wheels.

Distilling Apparatus.—There are two Williamson Bros. straight-

tube distillers, and two evaporators, Bureau pattern, with a combined capacity of 7,500 gallons of potable water at a temperature of 90 degrees Fahrenheit per day of 24 hours. The water-service pumps are used for the distiller-circulating water. There are two distiller feed pumps of the Worthington horizontal, duplex type, two combined brine and fresh-water pumps of the same type, and two trap pumps of the same type, except that they are vertical. There are two filters and two water meters fitted.

Ice Machine.—There is an Allen dense-air ice machine capable of producing the cooling effect of one ton of ice per day; steam cylinder, 9 inches, air-compressor cylinder, 5¾ inches, and air-expander cylinder, 4¾ inches in diameter; stroke, 10 inches. The circulating, water and primer pumps are single acting, each 1⅛ inches in diameter and 10 inches stroke. The cooling pipes connect to the ice tank, to the refrigerating room and to the scuttle butt.

Ventilating Fans.—There is in each engine-room hatch a 50-inch steel-plate fan, driven by a 12-H.P. electric motor, for engine-room ventilation only. For the general ventilation of the ship there are eight 50-inch steel-plate fans, located two on the berth deck and six on the splinter deck, for supplying air to the various parts of the ship. These fans are each driven by 12-H.P. electric motors. There are also three small exhausters driven by 3-H.P. electric motors, located two on berth deck and one in the steering-engine space, for exhausting air from the crews' W. C., officers' W. C., and the steering-engine room. All the fans were furnished by the Sturtevant Company, and the electric driving motors by the General Electric Company.

Steam Cutters.—There are two steam cutters, one 40 and the other 33 feet long. They have Ward boilers, type 5-G-1, round, and 5-D, square, respectively, compound engines and keel condensers. The cylinders for the 40-foot cutter are 5 and 10½ inches in diameter by 8 inches stroke, and those for the 33-foot cutter, 4 and 8 inches in diameter by 6 inches stroke.

Steering Engine.—There is a Williamson Bros. combined hand and steam-steering engine: cylinder, 14 inches diameter; stroke, 11 inches. With the steam gear the rudder can be put from hard

over to hard over in 20 seconds when the ship is going full speed. The engine is controlled from the conning tower and the pilot house by means of a hydraulic telemotor or by wire ropes.

Steam Windlass.—In the windlass house forward of the forward turret there is a steam windlass. The engine is reversible, double-cylinder, vertical, direct-acting, with cylinders 15 inches in diameter and a stroke of 14 inches. The windlass is fitted with two wild cats to take the chains.

Steam Winch.—There is a double-cylinder steam winch in the windlass house forward of forward turret. The cylinders are 8 inches in diameter; stroke, 8 inches. The winch is fitted with two drums for taking hawsers.

Electric Plant.—The installation consists in general of seven generating sets, 750 incandescent lights, 4 search lights, 2 sets of signalling apparatus, 1 main switch board, 3 main distribution boards, 7 auxiliary distribution boards, together with the necessary wire, wiring accessories, molding and fixtures and the motors given in table. The seven generating sets were made by the General Electric Company. In each set there is a 50-kilowatt dynamo of multipolar type, having a capacity of 625 ampères at 80 volts, compound-wound, six-pole. The engines driving the dynamos are compound, tandem, vertical, inverted; diameter of cylinders, 10½ and 18 inches; stroke, 8 inches. The engines are designed to run with full load at 310 revolutions per minute with 110 pounds steam pressure. The bed plate is common to both engine and dynamo. The incandescent lights are of 16 and 32-candle power, designed for 80 volts.

Each of the dynamos are connected to the main switch board, and to the equalizer board. The main switch board, containing only the panels for the dynamos and lighting and motor bus bars, distributes the current to the main distribution boards, which contain the switches of lighting circuits and motor feeders. The auxiliary distribution boards receive current from main distribution boards, and are for motors only.

The ship is wired on the three-wire system, with 80 volts between neutral wire and each leg, and 160 volts between outside legs. This gives a smaller amount of copper than would be neces-

AUXILIARY STEAM MACHINERY AND TOTAL NUMBER STEAM CYLINDERS.

Number.	Class.	Type.	Diameter of cylinders, and stroke.	Total number steam cylinders.	Pump capacity. Gallons per minute.	
			inches.		*each.*	*total.*
2	Main feed pumps	Worthington duplex	10 by 7 by 12	4	400	800
4	Auxiliary feed pumps	Worthington duplex	10 by 7 by 12	8	400	1,600
1	Auxiliary feed pumps	Worthington duplex	4½ by 3 by 4	2	65	65
2	Fire and bilge pumps	Worthington duplex	10 by 7 by 12	4	400	800
2	Water-service pumps	Worthington duplex	10 by 7 by 12	4	400	800
2	Bilge and sanitary pumps	Single, plunger	10 by 5	0	...	...
4	Ash-hoist engines	Williamson Bros.	4½ by 4½	8	...	...
1	Workshop engines	Vertical, single	7 by 7	1	...	...
2	Distiller feed pumps	Worthington duplex	4½ by 2¾ by 4	4	...	...
2	Brine and tank pumps	Worthington duplex	4½ by 2¾ by 4	4	...	...
2	Trap pumps	Worthington duplex	2 by 1⅝ by 2¾	4	...	...
1	Ice machine	Allen's dense air	9 by 10	1	...	...
1	Steering engine	Williamson Bros.	14 by 11	2	...	...
1	Steam windlass	Providence Steam Windlass Co.	15 by 14	2	...	...
1	Steam winch	Providence Steam Windlass Co.	8 by 8	2	...	...
7	Dynamo engines	General Electric Co.	10½ by 18 by 8	14	...	...
2	Air compressors	Rand Drill Co.	9½ by 4	4	...	...
8	Forced-draft blowers	Sturtevant	5 by 4	16	...	...
2	Auxiliary-condenser pumps	Worthington duplex	7½ by 8½ by 8½ by 10	4	...	...
2	Dynamo separator pumps	Worthington duplex	2 by 1½ by 2¾	4	...	...
1	Oil pump	Worthington duplex	2 by 1⅛ by 2¾	2	...	...
				94		
...	Main engines, air and circulating pumps			14	...	...
...	Steam cylinders of engines and pumps in cutters			10	...	...
...	.....	.....	.....	118	...	...

sary in the two-wire system and a wider range in speed of the motors, which are generally wound for both 80 and 160 volts.

There are four search lights, made by the General Electric Company, two mounted on a platform on the mainmast and two on a platform on the foremast. The projectors are 30 inches in diameter, and hand controlled. All lamps are of the horizontal type with combination hand or automatic feed, and designed for a current of 75 to 90 ampères at about 50 volts. The carbon holders are adjustable and the life of the carbon is six hours.

The signal apparatus is in two sets, one for each mast, of the usual Ardois type, and consists of four double signal lanterns to each set, cable connections and key board on the forward and after bridges.

Electric speed indicators and transmitters are fitted in the pilot house and in conning tower; also, electric helm indicators and electric steering-engine telegraphs.

There are thermostats in each coal bunker and in certain store rooms, with an annunciator on bulkhead forward of cabin.

ELECTRIC MOTORS.

Name.	Number.	Horsepower.	Revolutions.	Volts.	Ampères.
Upper-deck winches	4	25	320	80 or 160	150
Main-deck winches	2	25	320	80 or 160	150
Forward boat cranes	2	50	400	80 or 160	265
After boat cranes	2	20	350	80 or 160	111
Ventilating fans	10	12	500	80 or 160	64
Small exhausters	3	3	1,030	80	35
Turret turning	4	50	400	80	600
13-inch ammunition hoist	4	20	350	80 or 160	111
8-inch ammunition hoist	4	6	375	80 or 160	37
5-inch and 6 pdr. chain ammunition hoist	10	3.75	375	80 or 160	22
6-pounder winch ammunition hoist	2	6	375	80 or 160	37
13-inch elevating	4	2.5	300	80	30
13-inch rammer	4	5	775	80	60

Pneumatic Plant for Torpedoes.—There are two 9½-inch by 4-inch duplex torpedo compressors with the three-stage air cylinders and two accumulators. Both compressors and accu-

mulators are on the splinter deck, one of each forward and aft. The compressors were made by the Rand Drill Company.

OFFICIAL TRIAL.

The official full-speed trial of the *Kentucky* took place over the usual course (Cape Ann to Cape Porpoise) on Friday, the twenty-fourth of November, 1899, and consisted of two runs, one in each direction, over a measured course of thirty-three nautical miles. The first run was to the northward, and was with a light head wind and moderate sea. The second run was in the opposite direction, and was before the wind, the sea being about the same as during the run to the northward.

The mean speed, with corrections for wind, sea and tide applied, for the two runs, was 16.897 knots per hour, with a horsepower developed by the main engines of 12,081.90.

During the trial the fire rooms were kept connected, insuring equality of air pressure for each boiler. The forced draft system worked efficiently and regularly, maintaining a pressure of 1.02875 inch of water as a mean throughout the four hours of the trial.

The throttle valves were not changed from start to finish, being wide open, and the link-blocks of both engines were set so that the valves cut off steam at seven-tenths of the stroke.

Live steam was admitted to the receivers at times, the boiler pressure regulating the openings of the valves.

The speed of the two engines, as will be seen by reference to the synopsis, was kept practically together, and the resulting horsepower emphasizes that fact.

The engines, main and auxiliary, worked with the greatest regularity and smoothness, there being neither heating of journals nor thumping on the centers. No water was used externally on any of the journals save as a measure of ordinary precaution. The engines were remarkably free from vibrations, and the hull was devoid of all panting or indications of distress.

Following the return of the ship to the contractor's works, a careful examination was made of the machinery in all details and of the boilers, and the entire inspection developed an excellent condition throughout.

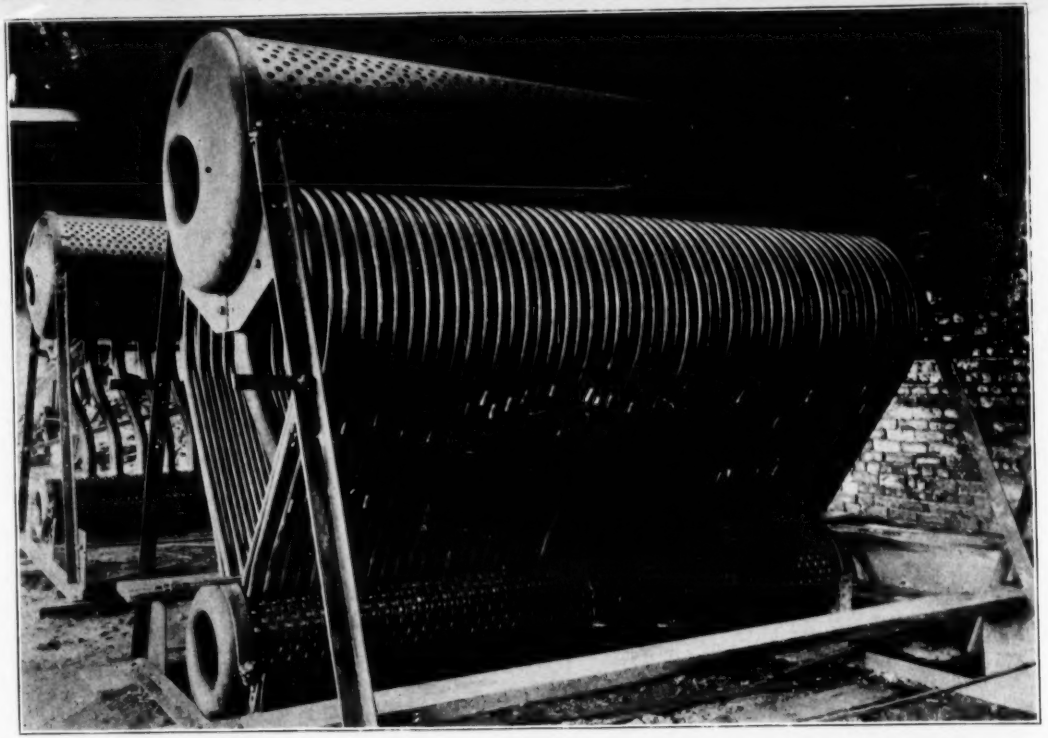
CONTRACT TRIAL DATA.

Draught of water, beginning of trial, forward, feet and inches	23- 4
aft, feet and inches	23-10
end of trial, forward, feet and inches	23- ½
aft, feet and inches	23- 8½
mean, forward, feet and inches	23- 2¼
aft, feet and inches	23- 9¼
average on trial, feet and inches	23- 5¾
Displacement (mean), tons	11,538
Area immersed midship section, square feet	1,618
Wetted surface, square feet	33,700
Mean speed, knots per hour	16.897
I.H.P., main engines only	12,081.90
main engines, air, circulating and feed pumps. (B)	12,179.31
all machinery in use	12,318.424
$Speed^3 \times$ area immersed midship section $\div$ I.H.P. (B)	643.87
$Speed^3 \times displacement^{\frac{2}{3}} \div$ I.H.P. (B)	203.33
I.H.P. per 100 square feet wetted surface. (B)	34.98
Screw propellers, number	2
number of blades each	3
diameter, feet and inches	16- 9
helicoidal area, square feet	84.2
pitch on trial, feet and inches	17- 3

SYNOPSIS OF STEAM LOG.

	Starboard.	*Port.*
Slip of screws, per cent	12.93	12.93
Revolutions of main engines per minute	114	114
mean	114	
Piston speed, feet per minute	912	912
Steam pressure (mean) at engines	170.5	163.8
first receiver, absolute	87.4	82.2
second receiver, absolute	30.5	28.8
Vacuum in condenser, inches	25.1	24.8
Throttle-valve opening	Wide.	
Steam cut-off in fraction of stroke from beginning, H.P	.692	.693
Steam cut-off in fraction of stroke from beginning, I.P	.70	.70
Steam cut-off in fraction of stroke from beginning, L.P.	.70	.70
Temperatures in degrees Fahrenheit, Engine rooms	88.1	
Temperatures in degrees Fahrenheit, Injection	44	44
Temperatures in degrees Fahrenheit, Discharge	126	127
Temperatures in degrees Fahrenheit, Feed at tank	149	149
Air pressure in fire rooms in inches of water	1.02875	
Mean effective pressures, H.P	70.69	67.99
Mean effective pressures, I.P	39.97	42.28
Mean effective pressures, L.P	16	15.75

		Starboard.	*Port.*
Aggregate equivalent pressure referred to L.P. piston		45.77	46.20
Revolutions or double strokes per minute,	Main air pumps	17.5	17.5
	Main circulating pumps	138	138
	Main feed pumps, average	34	
	Eight forced-draft blowers, av'ge	427	
I.H.P.	H.P. cylinder	1,678.88	1,613.92
	I.P. cylinder	2,231.11	2,359.79
	L.P. cylinder	2,102.50	2,095.70
	Collective, each main engine	6,012.49	6,069.41
	Main air pumps, each	8.2170	6.162
	Main circulating pumps	7.8332	11.2414
	Four main boiler feed pumps	56.328	
	Eight forced-draft blowers	61.264	
	Other auxiliaries	85.579	
	Collective, main engines, air, feed and circulating pumps. (B)	12,179.31	
	Total all machinery in use	12,318.424	
Square feet cooling surface (2) main condensers		14,100	
per I.H.P. main engines		1.16	
Heating surface in use		22,103.8	
Grate surface in use		684.8	
Square feet total H.S. per total I.H.P.		1.793	
I.H.P. per square foot grate surface, total		18	
ton machinery		11.19	
Kind of coal, Nuttallberg		New River (picked).	
Pounds per hour, total		32,391.8	
I.H.P., all machinery		2.6295	
main engine, auxiliary, circulating and feed pumps		2.6590	
square foot grate surface		47.31	
heating surface		1.465	



THORNYCROFT BOILER, "DARING" TYPE, BUILDING AT THE W. R. TRIGG CO.'S WORKS.

PRACTICAL DATA RELATING TO THE BUILDING OF BENT-TUBE BOILERS.

By John Platt, Associate Member.

The extended use of bent-tube boilers in our Navy brings to the fore the question of the mechanical appliances necessary for their economical production, and in giving a general description of the plan adopted in the laying out and building of these boilers, a Thornycroft boiler, generally known as the "Daring" type, has been selected as an example.

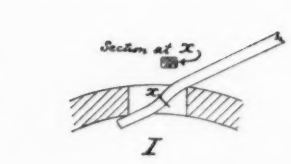
In the preparation of the barrels or drums the tube holes are drilled truly radial, and reamed out accurately with gages. The burrs are then taken off by means of a tool formed out of the tag end of a file (See Fig. I.) This tool is run round the hole two or three times, and takes the burrs off both inside and outside simultaneously.

The flanged heads are always made thick enough to allow of being machined where the different fittings are to be placed, the flange thus fitting against a flat surface; this being done, and the barrels otherwise finished, the upper and lower center barrels are fixed in their correct relative positions ready to receive the downtakes. For this purpose, a roughly-constructed frame is used. (See Fig. II.)

The lower barrel rests on two blocks and the upper one on the distance pieces shown.

Should the barrels not be truly cylindrical they will not lie evenly on the distance pieces, and it will be necessary to true them up. At this point great care should be taken to insure the proper distances apart of the barrel centers.

The shores *AA* are bolted at the upper ends to the top barrel through the tube holes, and the bottom ends are adjusted along the timbers *C* until the centers of the barrels are plumb over



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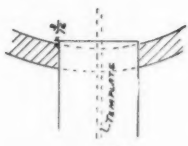
III



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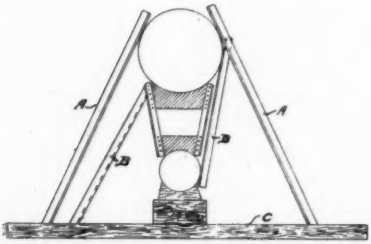

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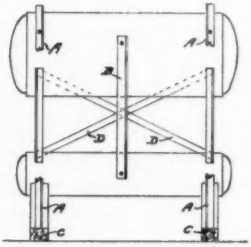

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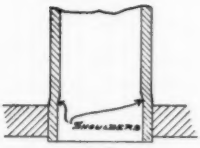

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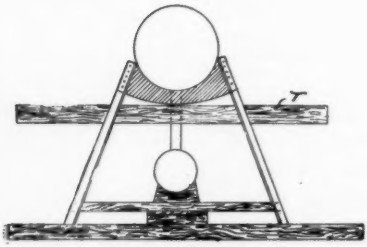
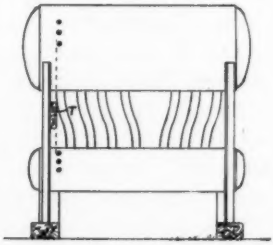




VII

each other, and then spiked down. Other shores may be placed at *B*, as shown, if necessary to secure steadiness. The top barrel is kept in position longitudinally by cross bracing *D*.

It is important that the framing should be firm and steady, as considerable force is often required to get the downtakes in place.

3. *Marking off Downtakes.*—These downtakes are the 4½-inch tubes connecting the upper and lower center drums in the Daring type of boiler used in the United States destroyers. A sheet-iron template is made, having the same outline as the downtakes, but somewhat longer. (See Fig. III.) It is placed in the holes in the barrels and the lengths of the downtakes scribed upon it, taking care to allow for the tubes projecting ¼ inch beyond the plates of both barrels. (Note.—The ¼ inch is measured at the sides of the hole, and the template will therefore project further. See Fig. IV.)

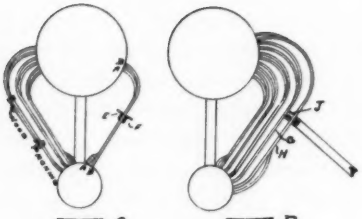
A scribing is taken for every downtake, as their lengths may sometimes vary. The lengths thus obtained are marked on the downtakes which have been previously bent. The ends are then cut off by a band saw, and the burrs filed off. It is then ascertained if an expander will enter freely.

Expanding Downtakes.—Commencing with the front end downtake, put the top end into its hole in the upper barrel, and tap it in with a mallet until it projects about one inch through, holding the downtake in the position shown on Fig. V. It is then turned a quarter round in the upper hole, bringing its lower end over the corresponding hole in the bottom barrel. It may now be dropped into the lower hole, a mallet being applied to the upper end. The ends should be left projecting ¼ inch into the interiors of the barrels. (See Fig. IV.)

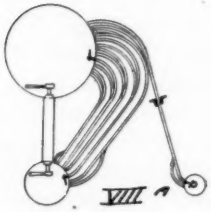
Place the next downtake in position, and continue with the others, the back end one being placed last.

Now see that the barrels have not moved out of position, or if so, make correction and proceed with expanding, commencing with the front end tube and finishing with the back end one.

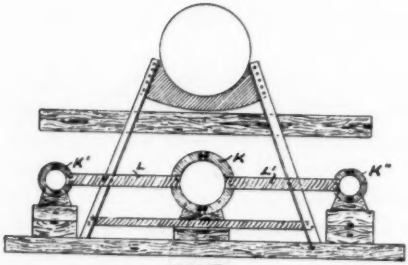
A line should be scribed on each downtake just outside the barrel plate and carefully observed during expanding, so that any movement of the tube in its hole may be detected and the tube



VII A VII B



VIII A



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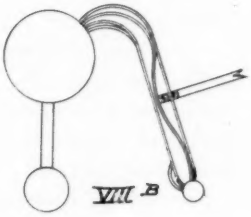
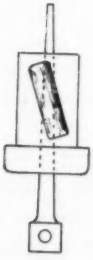


VIII B



IX

X

brought back to its original position by means of a mallet, before proceeding further with the expanding.

The downtakes may be expanded at both ends simultaneously.

It is a great mistake to over-expand the tubes, as this will render them brittle. After a little experience it is known, by the force required, when the expanding has gone far enough, but failing such experience it is safe to stop expanding when a shoulder can be just felt inside the tube. (See Fig. VI.)

Supporting Barrels while Fixing Generating Tubes.—Having expanded all the downtakes, the distance pieces supporting the boiler are removed, and the framing shown on Fig. VII, is substituted.

The timber *T* is adjusted so that its inside face is square with the center lines of the barrels and flush with a line joining the outside of the end tube holes.

Expanding Generating Tubes.—The generating tubes may now be inserted,* they having been previously bent, cut to length, all burrs removed, tested, galvanized on the outside, and the ends trued up with inside and outside reamers.

Commencing with the front end tubes of *A* row (Fig. VII[A]), the bottom end should be put into its hole first, using a mallet, and leaving $\frac{1}{4}$ inch projecting inside the lower barrel. Then insert the top end, leaving a like projection, and bring the tube into contact with the timber *T*. (Fig. VII.)

The tube will have to be sprung a little to be got into the holes. Great care must be taken that both ends of the tubes are in their proper holes, *e. g.* that the end tubes of row *A*, Fig. VII[A], are in the end holes of row *A*.

Having placed a front end tube of row *A* in position, next put in a *B* tube, and continue with *A* and *B* tubes alternately, building up a wall of tubes until the back end one is in place. If the right holes have been used, it will then be found that all the holes in rows *A* and *B* of both barrels are filled with tubes.

If the holes have not been correctly taken, it will be found that there is no hole left for one end of the last tube, and there-

*Before inserting the ends of tubes or downtakes, they, and the holes into which they are to be expanded, should be wiped with turpentine to remove grease and dirt.

fore the whole of the tubes must be taken out and placed in their proper holes.

It is immaterial whether or not the whole of the *A* and *B* tubes on one side are put in place before commencing on the other side, or whether both sides are proceeded with together.

All the tubes in rows *A* and *B* being now in place, the angle bars *E*, *F*, shown on Fig. VII[A], are clamped along them with bolts at each end. If the boiler is a long one, an extra bolt is put at the center of the angle bars, a tube having been left out to allow of this. These clamps help to keep the tubes in place while expanding.

The tubes may now be expanded, beginning at the front end and taking the *A* and *B* tubes alternately.

Similar precautions should be observed against tubes moving in the holes, and against over-expanding, as in the case of the downtakes.

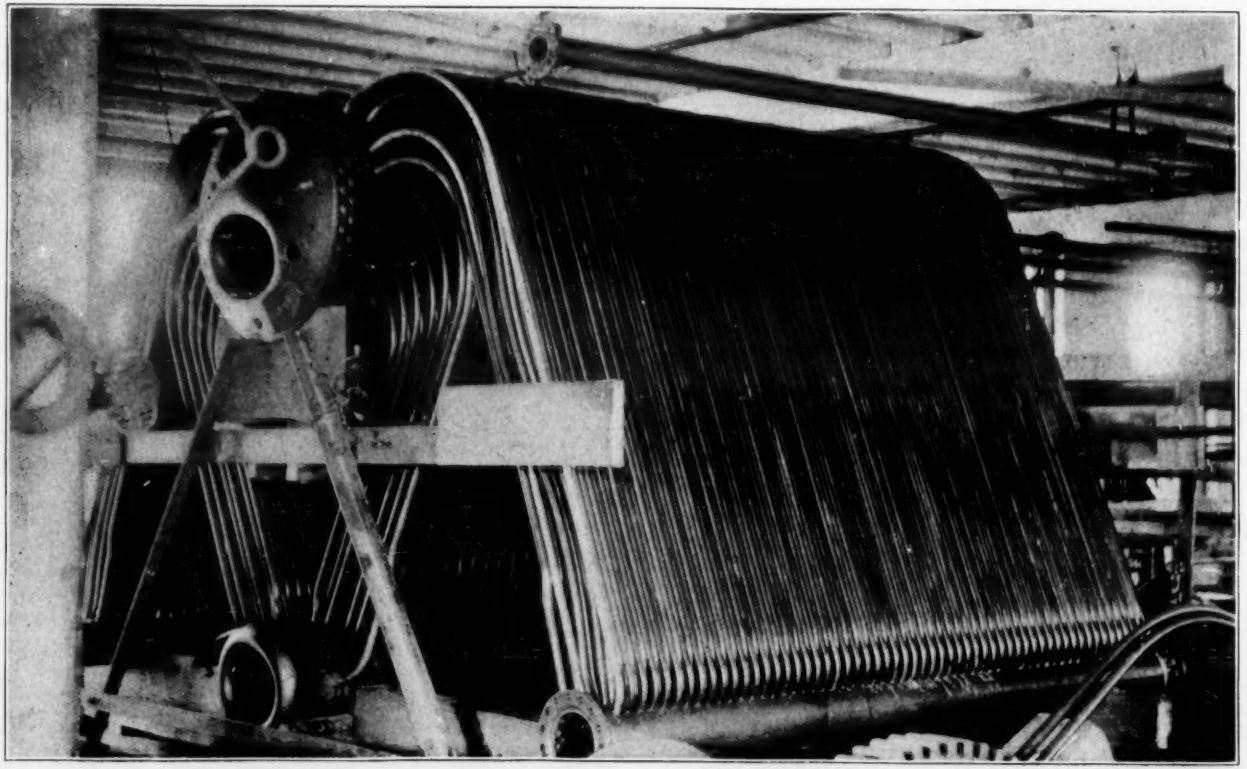
It is only when two rows of tubes form a "wall" that they are taken together. (The wall next the casing is an exception. See *Expanding Generating Tubes in the Wing Barrels.*)

In other cases the tubes entering one row only of holes in the lower barrel are taken, and in order to insure the proper spacing of the tubes throughout their length, pieces of wood packing of a thickness equal to the intended spaces are inserted between the tubes in about the positions shown on Fig. VII[A].

Care should be taken that the back end tubes in each row are square across the barrels, as otherwise the casing and uptake will not fit properly. It is also advisable that about every tenth tube should be tried as to "squareness," so that minute errors in the spacing may be detected and a large accumulated error avoided.

Owing to the closeness of the tubes, it is sometimes difficult to get a good hold for springing or forcing them into position. In such cases a piece of cord tied around the tube, with a loop at the end will be found a great help. By passing a rod through this, and placing one end against any convenient fulcrum, such as a tube hole, the action of the mallet may be assisted. (See Fig. X.)

Following this procedure, the whole of the tubes having their



ARRANGEMENT OF TUBES IN WING BARRELS.

lower ends in the bottom barrel may now be inserted and expanded. The last two rows forming the fire-box wall are treated similarly to rows *A* and *B*, except that the angle-bar clamps cannot be used, and these give place to the arrangement shown by Fig. VII^B, where *J* is a strip of wood placed between the tube wall *H* and the row of tubes *G*. Another strip is placed along the outside and shored up, clamping the tube wall between the two strips.

Wing Barrels.—The wing barrels should now be placed in their correct positions on each side of the lower central barrel.

The distances apart of their centers are maintained by the clips *KK'*, *K''* and struts *LL'*, shown on Fig. VIII, and they are wedged up on their supporting blocks until their centers are level with that of the lower central barrel.

Expanding Generating Tubes in the Wing Barrels.—The placing and expanding of the tubes in the wing barrels should proceed on the same lines as for the center barrel, with the following exceptions:

If there is a fire-box wall, angle-bar clamps should be used, the same as for rows *A* and *B*, but for the outer wall wood strips and shores may be necessary. (See Figs. VII^B and VIII^B.)

The rows of tubes forming the outside wall are not inserted and expanded together. The whole of the inner row should be expanded before the outer one is in place, and the outer tubes are expanded one by one as they are put in place. This is done so as always to leave an empty tube hole, which is used as a sight hole, close by the tube being expanded.

We now come to the question of the methods adopted in the expanding of the tubes. As before stated, the holes are, or should be, parallel and circular, and should on no account taper in such a direction as to facilitate the withdrawal of the tubes.

Ordinary roller expanders are used, with taper mandrels, the rollers being also tapered sufficiently to cause the expander to leave a cylindrical hole. The axles of the rollers are set at a slight angle so as to feed the mandrel forward when rotating. (See Fig. IX.) This angle is purposely exaggerated; in practice it is only about 1.75 degrees.

There is a risk, with cylindrical rollers, of a workman judging (by feel) that expanding has gone far enough when, in reality, he has only partly filled the hole in the tube plate.

There should be a distinct enlargement in the tube if the expanding has been properly performed.

The present English practice is to make the small tubes project ¼ inch beyond the plates, and to rely upon good expanding in every case to hold the tubes in the plate.

In connection with the holding power of boiler tubes expanded in various ways, we would refer to "London Engineering," Vol. XXIV, pp. 199, 202 and 335, and Vol. LV, p. 1. From the experiments there recorded it appears that, though beading does add considerably to the holding power of tubes, the strength of the attachment due to simple expanding, if properly carried out, is amply sufficient to withstand any force due to pressure, etc., likely to come upon them.

Experiments were made with crowbars upon tubes expanded in the ordinary manner, and it was found that a 1-inch bar could be bent without in any way dislodging a tube, and that when, with the aid of several men, using powerful levers, a tube was withdrawn, the force required was so great that the tube was in all instances bent out of shape and more or less crumpled up. Notwithstanding this fact, it is recommended that as an extra precaution, the ends of the tubes be trumpeted; this can be done by carefully drifting, or by the use of a special expander.

Tube Bending.—Tube bending is referred to separately, so that a description of the machine necessary for economical working can be given.

It is, of course, quite possible to bend all the tubes necessary upon a bending table, with a simple lever wheel and forms; and where it is only a question of building a single boiler, this plan is usually adopted.

Fig. XI shows a plan of the method of bending adopted by Messrs. W. D. Forbes & Co., who have built a number of bent-tube boilers for use in the United States Navy; it consists of a bending table, *A*, filled with slots or holes, for bolting down formers. A metal former, *B*, of the desired radius, is bolted in

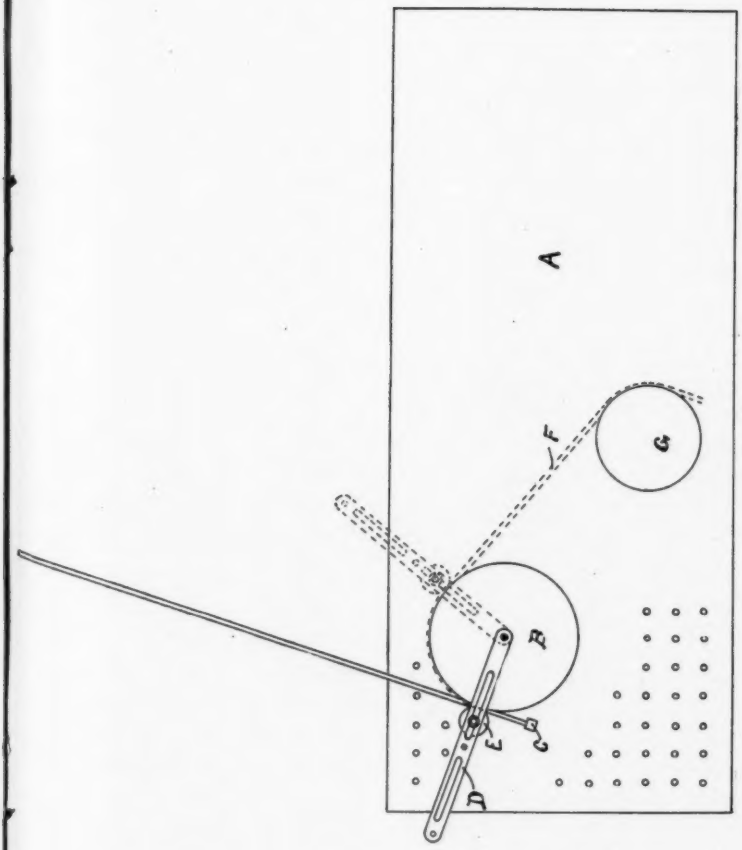


Fig XI.

the position shown. The tube to be bent is held in place by a plug, *C*, placed in the end of the tube. The arm *D*, fitted with adjustable roller *E*, is swung into position, and by means of a lever is rotated till the tube is bent to the desired position, *F*. A second former, *G*, is then placed as required to give the bend at the other end of the tube, the lever being used as in the first operation.

When curves of a large radius have to be made a wooden former is worked out of the necessary shape. A rod, with the end rounded so as not to injure the inside, is placed in the tube, the projecting end being long enough to form a lever; the tube is then pulled round the former, the rod being withdrawn gradually as the bend is made.

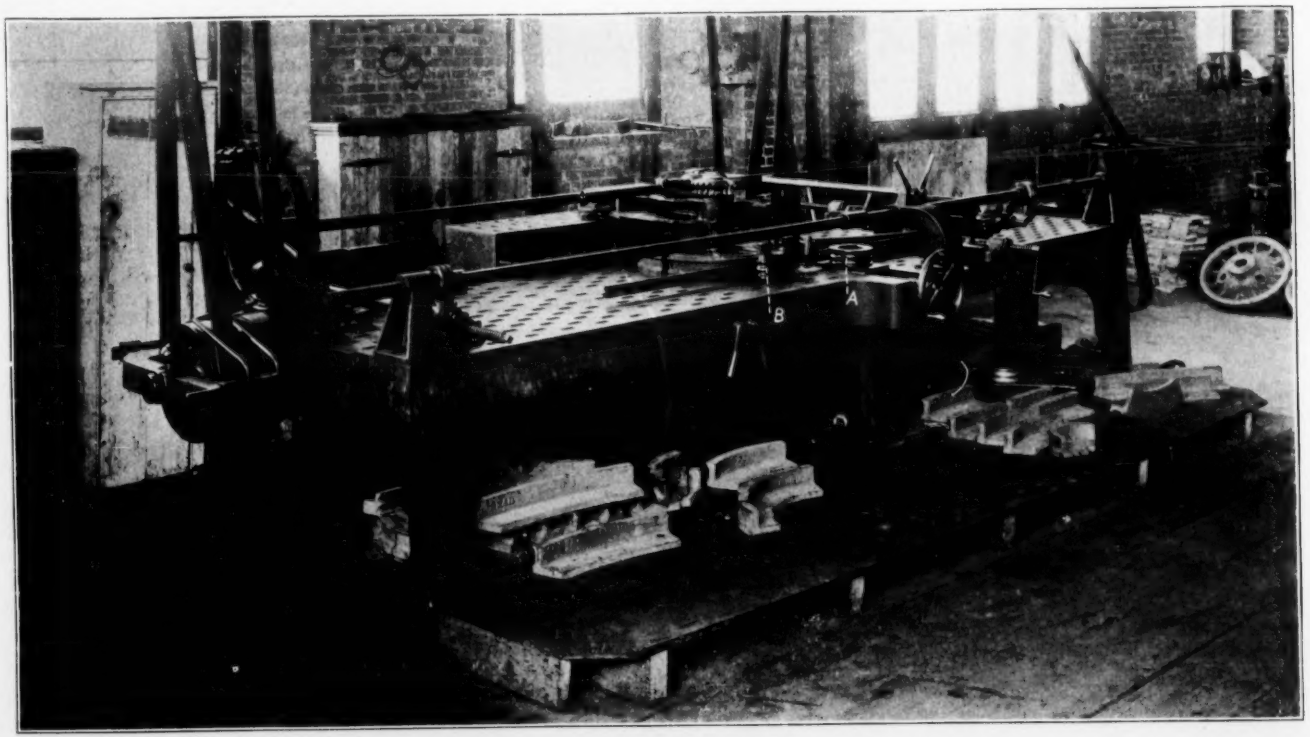
A system of trial and error has to be used to find the correct position of the formers to allow for the spring of the tubes.

Where a large number of tubes of a given shape have to be made special forms for each tube are provided, and bending is done economically on a special machine.

The machine used at the New York and Norfolk Navy Yards was manufactured by Messrs. The Pedrick & Ayer Co., under the patents of the late Mr. John Donaldson.

A photograph of the machine at the New York Navy Yard is here given. The machine consists of a cast-iron bending table 16 feet long by 4 feet 6 inches wide, with slots, for holding-down bolts, cast in. A swinging arm, *B*, worked by worm and spur gearing is provided for the main bend in any given tube. It is so arranged that it can be adjusted in either direction for position on the table. Around the center from which the arm is swung a *former* for the given radius to which the tube has to be bent is fixed. A cross slide in the bed plate, to the right of the main arm, operated by a screw-and-bevel gear, carries circular formers *A*. This is used for the deep central bend in tubes for boilers as of the *Speedy* class. At each end of the bed adjustable slides, worked by worm gearing, give the necessary bends at the ends of the tubes.

As there are a large number of similar tubes in a single boiler of this class, say over thirty on each side in each numbered row, the particular form of a tube of each special bend, or numbered



DONALDSON'S TUBE-BENDING MACHINE.

row, is laid out in full size on a board or metal plate, from the drawing. A template made of ¼-inch iron wire is bent corresponding to the center line of each shape; and, in turn, each template is used to adjust the various formers and vises on the table for that particular set of tubes, and from this setting all the tubes of that shape are bent. With this machine two tubes are bent at once, and the rapidity and exactness with which this is accomplished amply repays the builder for the preparations necessary where complete sets are needed.

With some shapes quite a number of formers are necessary, but they are readily made of cast iron, and can be kept on hand for an indefinite time for subsequent use. While the first bent tube of each set may show some deviation from the full-sized drawing as laid out, the necessary readjustment of formers are at once evident and can be quickly made, with the assurance that all the set will then be bent exactly as desired and with absolute uniformity, except where difference in degree of annealing shows some greater spring in individual tubes. This is readily corrected by a special hand vise used at the template table. Each tube after being bent is laid over the outline scribed on the template plate to insure accuracy of shape before trimming the ends. When the tube lies exactly over the outline as scribed on the plate, the ends are marked off from the outline on the plate, and the tubes taken to the cutting-off machine.

Cutting Off.—The bent tubes are cut to exact lengths, either by means of a revolving tool or a mechanical hack saw.

The bent tube is set in a stationary frame, the end to be cut being passed through a gripping vice on the bed of the machine, the tube being held firmly in place by a lever. Revolving cutters carried by a special chuck in the lathe head are automatically fed in, the end of the tube being cut off.

Another machine is provided for taking off the sharp corners left by the cutting-off machine. The tube is simply pressed against a revolving cutter head which takes the burs off both the inside and outside edges of the tube.

Testing.—The tubes are then taken to the testing machine. This machine consists of a pair of adjustable heads, fitted with

water connections, and means for quickly clamping the tube in place and making a water-tight joint at each end of the tube. The machine is so made that the connections can be adjusted to fit any shape of tube. Low-pressure water from a tank or city water is used to fill up the tube, the final pressure of 1,500 pounds per square inch being put on after the tube is filled up. After the pressure has been put on and the tube tested, the pressure is relieved and water allowed to run out into the funnel-shaped heads, and from there is run back to the pumping tank. The tubes are then stacked under their respective marks ready to be placed in the boiler.

CODE OF 1899—FOR CONDUCTING STEAM BOILER TRIALS.

At the last meeting of the American Society of Mechanical Engineers a revised code for conducting steam boiler trials was adopted and termed The Code of 1899. This new code was the result of the careful revision of the code of 1885 by a special committee, composed of Chas. E. Emery, Wm. Kent, Geo. H. Barrus, Chas. T. Porter, Robert H. Thurston, Robert W. Hunt, F. W. Dean, J. S. Coon, Wm. B. Potter. While the complete report accompanying the new code is too voluminous for reproduction here, the code itself, with a few selections from the preamble and the appendices, are desirable for the files of the JOURNAL.

In the preamble the Committee states that the changes are mainly in the line of amendments such as the experience of the last thirteen years has shown to be desirable. The amendments relate to the use of improved steam calorimeters, to sampling coal and determining its moisture, to calorific tests and analysis of coal, to analysis of flue gases, to smoke observations, to determinations of efficiency, and to methods of working out the 'heat balance.'

The tabular form of presenting the results of the test is somewhat changed and enlarged, and alterations in the text of the Code are made wherever needed. At the same time a second or 'short form' of report is added, for use in commercial tests or in cases where it is necessary to give only the principal data and results.

In the matter of instruments for determining the calorific value of fuel, it seems desirable that the committee should make a recommendation which is as specific as present knowledge and circumstances will warrant. It is agreed that some form of calorimeter in which the coal is burned in an atmosphere of

oxygen gas is to be preferred, and it is generally held that the most perfect apparatus thus far brought out is the Bomb Calorimeter, originally designed by Berthelot and modified by Mahler and Hempel. Several of these instruments are in use in this country, principally in the laboratories of engineering schools; but the apparatus is complicated and expensive, and it is not probable that many engineers will have the instrument as a part of their equipment for testing boilers. It is recommended, therefore, that samples of the coal used in testing boilers be sent for determinations of their heating value, to a testing laboratory provided with one of these instruments, or with some instrument which shall be proven to be equally good. (Article XVII, Code.)

The committee approves the conclusions of the 1885 Code to the effect that the standard "unit of evaporation" should be one pound of water at 212 degrees Fahrenheit evaporated into dry steam of the same temperature. This unit is equivalent to 965.7 British thermal units.

The committee recommends that, as far as possible, the capacity of a boiler be expressed in terms of the "number of pounds of water evaporated per hour from and at 212 degrees." It does not seem expedient, however, to abandon the widely-recognized measure of capacity of stationary or land boilers expressed in terms of "boiler horsepower."

The unit of commercial boiler horsepower adopted by the committee of 1885 was the same as that used in the reports of the boiler tests made at the Centennial Exhibition in 1876. The committee of 1885 reported in favor of this standard in language of which the following is an extract:

"Your committee, after due consideration, has determined to accept the Centennial standard, and to recommend that in all standard trials the commercial horsepower be taken as an evaporation of 30 pounds of water per hour from a feed-water temperature of 100 degrees Fahrenheit into steam at 70 pounds gage pressure, which shall be considered to be equal to $34\frac{1}{2}$ units of evaporation; that is, to $34\frac{1}{2}$ pounds of water evaporated from a feed-water temperature of 212 degrees Fahrenheit into steam at

the same temperature. This standard is equal to 33,305 thermal units per hour."

The present committee accepts the same standard, but reverses the order of two clauses in the statement, and slightly modifies them to read as follows:

The unit of commercial horsepower developed by a boiler shall be taken as 34½ units of evaporation per hour; that is, 34½ pounds of water evaporated per hour from a feed-water temperature of 212 degrees Fahrenheit into dry steam of the same temperature. This standard is equivalent to 33,317 British thermal units per hour. It is also practically equivalent to an evaporation of 30 pounds of water from a feed-water temperature of 100 degrees Fahrenheit into steam at 70 pounds gage pressure.

The committee also endorses the statement of the committee of 1885 concerning the commercial rating of boilers, changing somewhat its wording, so as to read as follows:

A boiler rated at any stated capacity should develop that capacity when using the best coal ordinarily sold in the market where the boiler is located, when fired by an ordinary fireman, without forcing the fires, while exhibiting good economy; and, further, the boiler should develop at least one-third more than the stated capacity when using the same fuel and operated by the same fireman, the full draft being employed and the fires being crowded; the available draft at the damper, unless otherwise understood, being not less than ½ inch water column.

RULES FOR CONDUCTING BOILER TRIALS—CODE OF 1899.

I. *Determine at the outset* the specific object of the proposed trial, whether it be to ascertain the capacity of the boiler, its efficiency as a steam generator, its efficiency and its defects under usual working conditions, the economy of some particular kind of fuel, or the effect of changes of design, proportion or operation; and prepare for the trial accordingly.

II. *Examine the boiler*, both outside and inside; ascertain the dimensions of grates, heating surfaces, and all important parts; and make a full record, describing the same, and illustrating special features by sketches. The area of heating surface is to be computed from the surfaces of shells, tubes, furnaces and fire-

boxes in contact with the fire or hot gases. The outside diameter of water tubes and the inside diameter of fire tubes are to be used in the computation. All surfaces below the mean water level which have water on one side and products of combustion on the other are to be considered as water-heating surface, and all surfaces above the mean water-level which have steam on one side and products of combustion on the other are to be considered as superheating surface.

III. *Notice the general condition* of the boiler and its equipment, and record such facts in relation thereto as bear upon the objects in view.

If the object of the trial is to ascertain the maximum economy or capacity of the boiler as a steam generator, the boiler and all its appurtenances should be put in a first-class condition. Clean the heating surface inside and outside, remove clinkers from the grates and from the sides of the furnace. Remove all dust, soot and ashes from the chambers, smoke connections and flues. Close air leaks in the masonry and poorly fitted cleaning doors. See that the damper will open wide and close tight. Test for air leaks by firing a few shovels of smoky fuel and immediately closing the damper, observing the escape of smoke through the crevices, or by passing the flame of a candle over cracks in the brickwork.

IV. *Determine the character of the coal* to be used. For tests of the efficiency or capacity of the boiler for comparison with other boilers the coal should, if possible, be of some kind which is commercially regarded as a standard. For New England and that portion of the country east of the Allegheny Mountains, good anthracite egg coal, containing not over 10 per cent. of ash, and semi-bituminous Clearfield (Pa.), Cumberland (Md.), and Pocahontas (Va.) coals are thus regarded. West of the Allegheny Mountains, Pocahontas (Va.) and New River (W. Va.) semi-bituminous, and Youghiogheny or Pittsburg bituminous coals are recognized as standards.* There is no special grade

* These coals are selected because they are about the only coals which possess the essentials of excellence of quality, adaptability to various kinds of furnaces, grates, boilers and methods of firing, and wide distribution and general accessibility in the markets.

of coal mined in the Western States which is widely recognized as of superior quality or considered as a standard coal for boiler testing. Big Muddy lump, an Illinois coal mined in Jackson County, Ill., is suggested as being of sufficiently high grade to answer these requirements in districts where it is more conveniently obtainable than the other coals mentioned above.

For tests made to determine the performance of a boiler with a particular kind of coal, such as may be specified in a contract for the sale of a boiler, the coal used should not be higher in ash and in moisture than that specified, since increase in ash and moisture above a stated amount is apt to cause a falling off of both capacity and economy in greater proportion than the proportion of such increase.

V. *Establish the correctness of all apparatus* used in the test for weighing and measuring. These are:

1. Scales for weighing coal, ashes and water.

2. Tanks, or water meters for measuring water. Water meters, as a rule, should only be used as a check on other measurements. For accurate work the water should be weighed or measured in a tank.

3. Thermometers and pyrometers for taking temperatures of air, steam, feed water, waste gases, etc.

4. Pressure gages, draught gages, etc.

The kind and location of the various pieces of testing apparatus must be left to the judgment of the person conducting the test; always keeping in mind the main object, *i.e.*, to obtain authentic data.

VI. *See that the boiler is thoroughly heated* before the trial, to its usual working temperature. If the boiler is new and of a form provided with a brick setting, it should be in regular use at least a week before the trial, so as to dry and heat the walls. If it has been laid off and become cold, it should be worked before the trial until the walls are well heated.

VII. *The boiler and connections* should be proved to be free from leaks before beginning a test, and all water connections, including blow and extra feed pipes, should be disconnected, stopped

with blank flanges, or bled through special openings beyond the valves, except the particular pipe through which water is to be fed to the boiler during the trial. During the test the blow-off and feed pipes should remain exposed to view.

If an injector is used, it should receive steam directly through a felted pipe from the boiler being tested.*

If the water is metered after it passes the injector, its temperature should be taken at the point where it leaves the injector. If the quantity is determined before it goes to the injector, the temperature should be determined on the suction side of the injector, and if no change of temperature occurs other than that due to the injector, the temperature thus determined is properly that of the feed water. When the temperature changes between the injector and the boiler, as by the use of a heater or by radiation, the temperature at which the water enters and leaves the injector and that at which it enters the boiler should all be taken. In that case the weight to be used is that of the water leaving the injector, computed from the heat units if not directly measured, and the temperature, that of the water entering the boiler.

Let w = weight of water entering the injector.
x = weight of steam entering the injector.
h_1 = heat units per pound of water entering injector.
h_2 = heat units per pound of steam entering injector.
h_3 = heat units per pound of water leaving injector.

Then, $w + x$ = weight of water leaving injector.

$$x = w\frac{h_3 - h_1}{h_2 - h_3}.$$

See that the steam main is so arranged that water of condensation cannot run back into the boiler.

*In feeding a boiler undergoing test with an injector taking steam from another boiler, or from the main steam pipe from several boilers, the evaporative results may be modified by a difference in the quality of the steam from such source compared with that supplied by the boiler being tested, and in some cases the connection to the injector may act as a drip for the main steam pipe. If it is known that the steam from the main pipe is of the same pressure and quality as that furnished by the boiler undergoing the test, the steam may be taken from such main pipe.

VIII. *Duration of the Test.*—For tests made to ascertain either the maximum economy or the maximum capacity of a boiler, irrespective of the particular class of service for which it is regularly used, the duration should be at least 10 hours of continuous running. If the rate of combustion exceeds 25 pounds of coal per square foot of grate surface per hour, it may be stopped when a total of 250 pounds of coal has been burned per square foot of grate.

In cases where the service requires continuous running for the whole 24 hours of the day, with shifts of firemen a number of times during that period, it is well to continue the test for at least 24 hours.

When it is desired to ascertain the performance under the working conditions of practical running, whether the boiler be regularly in use 24 hours a day or only a certain number of hours out of each 24, the fires being banked the balance of the time, the duration should not be less than 24 hours.

IX. *Starting and Stopping a Test.*—The conditions of the boiler and furnace in all respects should be, as nearly as possible, the same at the end as at the beginning of the test. The steam pressure should be the same; the water level the same; the fire upon the grates should be the same in quantity and condition; and the walls, flues, etc., should be of the same temperature. Two methods of obtaining the desired equality of conditions of the fire may be used, viz: those which were called in the Code of 1885 "the standard method" and "the alternate method," the latter being employed where it is inconvenient to make use of the standard method.*

X. *Standard Method of Starting and Stopping a Test.*—Steam being raised to the working pressure, remove rapidly all the fire from the grate, close the damper, clean the ash pit, and as quickly as possible start a new fire with weighed wood and coal, noting

*The committee concludes that it is best to retain the designations "standard" and "alternate," since they have become widely known and established in the minds of engineers and in the reprints of the Code of 1885. Many engineers prefer the "alternate" to the "standard" method on account of its being less liable to error due to cooling of the boiler at the beginning and end of a test.

the time and the water level* while the water is in a quiescent state, just before lighting the fire.

At the end of the test remove the whole fire, which has been burned low, clean the grates and ash pit, and note the water level when the water is in a quiescent state, and record the time of hauling the fire. The water level should be as nearly as possible the same as at the beginning of the test. If it is not the same, a correction should be made by computation, and not by operating the pump after the test is completed.

XI. *Alternate Method of Starting and Stopping a Test.*—The boiler being thoroughly heated by a preliminary run, the fires are to be burned low and well cleaned. Note the amount of coal left on the grate as nearly as it can be estimated; note the pressure of steam and the water level. Note the time, and record it as the starting time. Fresh coal which has been weighed should now be fired. The ash pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave a bed of coal on the grates of the same depth, and in the same condition, as at the start. When this stage is reached, note the time and record it as the stopping time. The water level and steam pressures should previously be brought as nearly as possible to the same point as at the start. If the water level is not the same as at the start, a correction should be made by computation, and not by operating the pump after the test is completed.

XII. *Uniformity of Conditions.*—In all trials made to ascertain maximum economy or capacity, the conditions should be maintained uniformly constant. Arrangements should be made to dispose of the steam so that the rate of evaporation may be kept the same from beginning to end. This may be accomplished in a single boiler by carrying the steam through a waste steam pipe, the discharge from which can be regulated as desired. In

* The gage glass should not be blown out within an hour before the water level is taken at the beginning and end of a test, otherwise an error in the reading of the water level may be caused by a change in the temperature and density to the water in the pipe leading from the bottom of the glass into the boiler.

a battery of boilers, in which only one is tested, the draft may be regulated on the remaining boilers, leaving the test boiler to work under a constant rate of production.

Uniformity of conditions should prevail as to the pressure of steam, the height of water, the rate of evaporation, the thickness of fire, the times of firing and quantity of coal fired at one time, and as to the intervals between the times of cleaning the fires.

The method of firing to be carried on in such tests should be dictated by the expert or person in responsible charge of the test, and the method adopted should be adhered to by the fireman throughout the test.

XIII. *Keeping the Records.*—Take note of every event connected with the progress of the trial, however unimportant it may appear. Record the time of every occurrence and the time of taking every weight and every observation.

The coal should be weighed and delivered to the fireman in equal proportions, each sufficient for not more than one hour's run, and a fresh portion should not be delivered until the previous one has all been fired. The time required to consume each portion should be noted, the time being recorded at the instant of firing the last of each portion. It is desirable that at the same time the amount of water fed into the boiler should be accurately noted and recorded, including the height of the water in the boiler, and the average pressure of steam and temperature of feed during the time. By thus recording the amount of water evaporated by successive portions of coal, the test may be divided into several periods if desired, and the degree of uniformity of combustion, evaporation and economy analyzed for each period. In addition to these records of the coal and the feed water, half-hourly observations should be made of the temperature of the feed water, of the flue gases, of the external air in the boiler room, of the temperature of the furnace when a furnace pyrometer is used, also of the pressure of steam and of the readings of the instruments for determining the moisture in the steam. A log should be kept on properly prepared blanks containing columns for record of the various observations.

When the "standard method" of starting and stopping the

test is used, the hourly rate of combustion and of evaporation and the horsepower should be computed from the records taken during the time when the fires are in active condition. This time is somewhat less than the actual time which elapses between the beginning and end of the run. The loss of time due to kindling the fire at the beginning and burning it out at the end makes this course necessary.

XIV. *Quality of Steam.*—The percentage of moisture in the steam should be determined by the use of either a throttling or a separating steam calorimeter. The sampling nozzle should be placed in the vertical steam pipe rising from the boiler. It should be made of ½-inch pipe, and should extend across the diameter of the steam pipe to within half an inch of the opposite side, being closed at the end and perforated with not less than twenty ⅛-inch holes equally distributed along and around its cylindrical surface, but none of these holes should be nearer than ½ inch to the inner side of the steam pipe. The calorimeter and the pipe leading to it should be well covered with felting. Whenever the indications of the throttling or separating calorimeter show that the percentage of moisture is irregular, or occasionally in excess of three per cent., the results should be checked by a steam separator placed in the steam pipe as close to the boiler as convenient, with a calorimeter in the steam pipe just beyond the outlet from the separator. The drip from the separator should be caught and weighed, and the percentage of moisture computed therefrom added to that shown by the calorimeter.

Superheating should be determined by means of a thermometer placed in a mercury well inserted in the steam pipe. The degree of superheating should be taken as the difference between the reading of the thermometer for superheated steam and the readings of the same thermometer for saturated steam at the same pressure as determined by a special experiment, and not by reference to steam tables.

XV. *Sampling the Coal and Determining its Moisture.*—As each barrow load or fresh portion of coal is taken from the coal pile, a representative shovelful is selected from it and placed in a barrel or box in a cool place and kept until the end of the

trial. The samples are then mixed and broken into pieces not exceeding one inch in diameter, and reduced by the process of repeated quartering and crushing until a final sample weighing about five pounds is obtained, and the size of the larger pieces are such that they will pass through a sieve with ¼-inch meshes. From this sample two one-quart, airtight, glass preserving jars, or other airtight vessels which will prevent the escape of moisture from the sample, are to be promptly filled, and these samples are to be kept for subsequent determinations of moisture and of heating value and for chemical analyses. During the process of quartering, when the sample has been reduced to about 100 pounds, a quarter to a half of it may be taken for an approximate determination of moisture. This may be made by placing it in a shallow iron pan, not over three inches deep, carefully weighing it, and setting the pan in the hottest place that can be found on the brickwork of the boiler setting or flues, keeping it there for at least twelve hours, and then weighing it. The determination of moisture thus made is believed to be approximately accurate for anthracite and semi-bituminous coals, and also for Pittsburg or Youghiogheny coal; but it cannot be relied upon for coals mined west of Pittsburg, or for other coals containing inherent moisture. For these latter coals it is important that a more accurate method be adopted. The method recommended by the committee for all accurate tests, whatever the character of the coal, is described as follows:

Take one of the samples contained in the glass jars, and subject it to a thorough air drying, by spreading it in a thin layer and exposing it for several hours to the atmosphere of a warm room, weighing it before and after, thereby determining the quantity of surface moisture it contains. Then crush the whole of it by running it through an ordinary coffee mill adjusted so as to produce somewhat coarse grains (less than $\frac{1}{16}$ inch), thoroughly mix the crushed sample, select from it a portion of from 10 to 50 grams, weigh it in a balance which will easily show a variation as small as 1 part in 1,000, and dry it in an air or sand bath at a temperature between 240 and 280 degrees Fahrenheit for one hour. Weigh it and record the loss, then heat and

weigh it again repeatedly, at intervals of an hour or less, until the minimum weight has been reached and the weight begins to increase by oxidation of a portion of the coal. The difference between the original and the minimum weight is taken as the moisture in the air-dried coal. This moisture test should preferably be made on duplicate samples, and the results should agree within 0.3 to 0.4 of 1 per cent., the mean of the two determinations being taken as the correct result. The sum of the percentage of moisture thus found and the percentage of surface moisture previously determined is the total moisture.

XVI. *Treatment of Ashes and Refuse.*—The ashes and refuse are to be weighed in a dry state. If it is found desirable to show the principal characteristics of the ash, a sample should be subjected to a proximate analysis and the actual amount of incombustible material determined. For elaborate trials a complete analysis of the ash and refuse should be made.

XVII. *Clorific Tests and Analysis of Coal.*—The quality of the fuel should be determined either by heat test or by analysis, or by both.

The rational method of determining the total heat of combustion is to burn the sample of coal in an atmosphere of oxygen gas, the coal to be sampled as directed in Article XV of this code.

The chemical analysis of the coal should be made only by an expert chemist. The total heat of combustion computed from the results of the ultimate analysis may be obtained by the use of Dulong's formula (with constants modified by recent determinations), viz: $14{,}600\ C + 62{,}000\left(H - \frac{O}{8}\right) + 4{,}000\ S$, in which C, H, O and S refer to the proportions of carbon, hydrogen, oxygen, and sulphur respectively, as determined by the ultimate analysis.*

It is desirable that a proximate analysis should be made,

*Favre and Silberman gives 14,544 B.T.U. per pound carbon; Berthelot, 14,647 B.T.U. Favre and Silberman give 62,032 B.T.U. per pound hydrogen; Thomsen, 61,816 B.T.U.

thereby determining the relative proportions of volatile matter and fixed carbon. These proportions furnish an indication of the leading characteristics of the fuel, and serve to fix the class to which it belongs. As an additional indication of the characteristics of the fuel, the specific gravity should be determined.

XVIII. *Analysis of Flue Gases.*—The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing, or of different kinds of furnaces. In making these analyses great care should be taken to procure average samples, since the composition is apt to vary at different points of the flue. The composition is also apt to vary from minute to minute, and for this reason the drawings of gas should last a considerable period of time. Where complete determinations are desired, the analyses should be entrusted to an expert chemist. For approximate determinations the Orsat* or the Hempel† apparatus may be used by the engineer.

For the continuous indication of the amount of carbonic acid present in the flue gases, an instrument may be employed which shows the weight of the sample of gas passing through it.

XIX. *Smoke Observations.*—It is desirable to have a uniform system of determining and recording the quantity of smoke produced where bituminous coal is used. The system commonly employed is to express the degree of smokiness by means of percentages dependent upon the judgment of the observer. The committee does not place much value upon a percentage method, because it depends so largely upon the personal element, but if this method is used, it is desirable that, so far as possible, a definition be given in explicit terms as to the basis and method employed in arriving at the percentage. The actual measurement of a sample of soot and smoke by some form of meter is to be preferred.

XX. *Miscellaneous.*—In tests for purposes of scientific research, in which the determination of all the variables entering into the

* See R. S. Hale's paper on "Flue Gas Analysis," "Transactions," Vol. XVIII, p. 901.

† See Hempel's "Methods of Gas Analysis" (Macmillan & Co.).

test is desired, certain observations should be made which are in general unnecessary for ordinary tests. These are the measurement of the air supply, the determination of its contained moisture, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, and (by condensation of all the steam made by the boiler) of the total heat imparted to the water.

As these determinations are rarely undertaken, it is not deemed advisable to give directions for making them.

XXI. *Calculations of Efficiency.*—Two methods of defining and calculating the efficiency of a boiler are recommended. They are:

1. Efficiency of the boiler $= \frac{\text{Heat absorbed per lb. combustible}}{\text{Calorific value of 1 lb. combustible}}$.

2. Efficiency of boiler and grate $= \frac{\text{Heat absorbed per lb. coal}}{\text{Calorific value of 1 lb. coal}}$.

The first of these is sometimes called the efficiency based on combustible, and the second the efficiency based on coal. The first is recommended as a standard of comparison for all tests, and this is the one which is understood to be referred to when the word "efficiency" alone is used without qualification. The second, however, should be included in a report of a test, together with the first, whenever the object of the test is to determine the efficiency of the boiler and furnace together with the grate (or mechanical stoker), or to compare different furnaces, grates, fuels or methods of firing.

The heat absorbed per pound of combustible (or per pound coal) is to be calculated by multiplying the equivalent evaporation from and at 212 degrees per pound combustible (or coal) by 965.7.

XXII. *The Heat Balance.*—An approximate "heat balance," or statement of the distribution of the heating value of the coal among the several items of heat utilized and heat lost may be included in the report of a test when analyses of the fuel and of the chimney gases have been made. It should be reported in the following form:

HEAT BALANCE, OR DISTRIBUTION OF THE HEATING VALUE OF THE COMBUSTIBLE.

Total heat value of 1 pound of combustible.....B.T.U.

.....	B.T.U.	Per cent.
1. Heat absorbed by the boiler = evaporation from and at 212 degrees per pound of combustible $\times 965.7$		
2. Loss due to moisture in coal = per cent. of moisture referred to combustible $\div 100 \times [(212 - t) + 966 + 0.48\,(T - 212)]$. t = temperature of air in the boiler room, T = that of the flue gases		
3. Loss due to moisture formed by the burning of hydrogen = per cent. of hydrogen to combustible $\div 100 \times 9 \times [(212 - t) + 966 + 0.48(T - 212)]$		
4.* Loss due to heat carried away in the dry chimney gases = weight of gas per pound of combustible $\times 0.24 \times (T - t)$		
5.† Loss due to incomplete combustion of carbon = $\frac{CO}{CO_2 + CO} \times \frac{\text{per cent. C in combustible}}{100} \times 10,150$		
6. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation, and unaccounted for. (Some of these losses may be separately itemized if data are obtained from which they may be calculated)		
Totals		100.00

* The weight of gas per pound of carbon burned may be calculated from the gas analyses as follows:

Dry gas per pound carbon $= \frac{11\,CO_2 + 8\,O + 7\,(CO + N)}{3\,(CO_2 + CO)}$, in which CO_2, CO, O and N are the percentages by volume of the several gases. As the sampling and analyses of the gases in the present state of the art are liable to considerable errors, the result of this calculation is usually only an approximate one. The heat balance itself is also only approximate for this reason, as well as for the fact that it is not possible to determine accurately the percentage of unburned hydrogen or hydrocarbons in the flue gases.

The weight of dry gas per pound of combustible is found by multiplying the dry gas per pound of carbon by the percentage of carbon in the combustible, and dividing by 100.

† CO_2 and CO are respectively the percentage by volume of carbonic acid and carbonic oxide in the flue gases. The quantity 10,150 = number heat units generated by burning to carbonic acid one pound of carbon contained in carbonic oxide.

XXIII. *Report of the Trial.*—The data and results should be reported in the manner given in either one of the two following tables, omitting lines where the tests have not been made as elaborately as provided for in such tables. Additional lines may be added for data relating to the specific object of the test. The extra lines should be classified under the headings provided in the tables, and numbered as per preceding line, with sub letters

a, *b*, etc. The Short Form of Report, Table No. 2, is recommended for commercial tests and, as a convenient form of abridging the longer form for publication, when saving of space is desirable. For elaborate trials, it is recommended that the full log of the trial be shown graphically by means of a chart.

TABLE No. 1.—DATA AND RESULTS OF EVAPORATIVE TEST.

Arranged in accordance with the Complete Form advised by the Boiler Test Committee of the American Society of Mechanical Engineers. Code of 1899.

Made by.....of.....boiler at.....to determine.....

.....

Principal conditions governing the trial.....

.....

.....

*Kind of fuel**.....

Kind of furnace.....

State of the weather.....

Method of starting and stopping the test ("standard" or "alternate," Art. X and XI, Code).....

1. *Date of trial*.....
2. *Duration of trial*..... hours.

Dimensions and Proportions.

A complete description of the boiler, and drawings of the same if of unusual type, should be given on an annexed sheet. (See Appendix X.)

3. *Grate surface*.....*width*.....*length*.....*area*..... sq. ft.
4. Height of furnace..... ins.
5. Approximate width of air spaces in grate..... in.
6. Proportion of air space to whole grate surface..... per cent.
7. *Water-heating surface*..... sq. ft.
8. *Superheating surface*..... "
9. Ratio of water-heating surface to grate surface..... — to 1.
10. Ratio of minimum draft area to grate surface..... 1 to —

Average Pressures.

11. *Steam pressure by gage*.....lbs. per sq. in.
12. *Force of draft between damper and boiler*.....ins. of water.
13. Force of draft in furnace..... " "
14. Force of draft or blast in ashpit..... " "

*The items printed in italics correspond to the items in the "Short Form of Code."

Average Temperatures.

15.	Of external air	deg.
16.	Of fireroom	"
17.	Of steam	"
18.	Of feed water entering heater	"
19.	Of feed water entering economizer	"
20.	*Of feed water entering boiler*	"
21.	*Of escaping gases from boiler*	"
22.	Of escaping gases from economizer	"

Fuel.

23.	Size and condition	
24.	Weight of wood used in lighting fire	lbs.
25.	*Weight of coal as fired* *	"
26.	*Percentage of moisture in coal* †	per cent.
27.	*Total weight of dry coal consumed*	lbs.
28.	*Total ash and refuse*	"
29.	Quality of ash and refuse	
30.	Total combustible consumed	"
31.	*Percentage of ash and refuse in dry coal*	per cent.

Proximate Analysis of Coal.

		Of Coal.	Of Combustible.
32.	Fixed carbon	per cent.	per cent.
33.	Volatile matter	"	"
34.	Moisture	"	——
35.	Ash	"	——
		100 per cent.	100 per cent.
36.	Sulphur separately determined	"	"

Ultimate Analysis of Dry Coal.

(Art. XVII, Code.)

		Of Coal.	Of Combustible.
37.	Carbon (C)	per cent.	per cent.
38.	Hydrogen (H)	"	"
39.	Oxygen (O)	"	"
40.	Nitrogen (N)	"	"
41.	Sulphur (S)	"	"
42.	Ash	"	——
		100 per cent.	100 per cent.
43.	Moisture in sample of coal as received	"	"

*Including equivalent of wood used in lighting the fire, not including unburnt coal withdrawn from furnace at times of cleaning and at end of test. One pound of wood is taken to be equal to 0.4 pound of coal, or, in case greater accuracy is desired, as having a heat value equivalent to the evaporation of 6 pounds of water from and at 212 degrees per pound. ($6 \times 965.7 = 5{,}794$ B.T.U.) The term "as fired" means in its actual condition, including moisture.

† This is the total moisture in the coal as found by drying it artificially, as described in Art. XV. of Code.

Analysis of Ash and Refuse.

44.	Carbon	per cent.
45.	Earthy matter	"

Fuel per Hour.

46.	*Dry coal consumed per hour*	lbs.
47.	Combustible consumed per hour	"
48.	*Dry coal per square foot of grate surface per hour*	"
49.	Combustible per square foot of water-heating surface per hour	"

Calorific Value of Fuel.
(Art. XVII, Code.)

50.	*Calorific value by oxygen calorimeter, per lb. of dry coal*	B.T.U.
51.	*Calorific value by oxygen calorimeter, per lb. of combustible,*	"
52.	Calorific value by analysis, per lb. of dry coal*	"
53.	Calorific value by analysis, per lb. of combustible	"

Quality of Steam.

54.	*Percentage of moisture in steam*	per cent.
55.	*Number of degrees of superheating*	deg.
56.	Quality of steam (dry steam = unity). (For exact determination of the factor of correction for quality of steam see Appendix XVIII.)	

Water.

57.	*Total weight of water fed to boiler* †	lbs.
58.	Equivalent water fed to boiler from and at 212 degrees	"
59.	*Water actually evaporated, corrected for quality of steam*	"
60.	Factor of evaporation ‡	"
61.	Equivalent water evaporated into dry steam from and at 212 degrees. § (Item 59 × Item 60.)	"

Water per Hour.

62.	*Water evaporated per hour, corrected for quality of steam*	"
63.	*Equivalent evaporation per hour from and at 212 degrees* §	"
64.	*Equivalent evaporation per hour from and at 212 degrees per square foot of water-heating surface* §	"

* See formula for calorific value under Article XVII of Code.

† Corrected for inequality of water level and of steam pressure at beginning and end of test.

‡ Factor of evaporation $= \frac{H-h}{965.7}$, in which H and h are respectively the total heat in steam of the average observed pressure, and in water of the average observed temperature of the feed.

§ The symbol "U. E.," meaning "Units of Evaporation," may be conveniently substituted for the expression "Equivalent water evaporated into dry steam from and at 212 degrees," its definition being given in a foot note.

Horsepower.

65. *Horsepower developed.* (34½ *pounds of water evaporated per hour into dry steam from and at 212 degrees, equals one horsepower*)*..... H.P.
66. *Builders' rated horsepower*..... "
67. *Percentage of builders' rated horsepower developed*..... per cent.

Economic Results.

68. *Water apparently evaporated under actual conditions per pound of coal as fired.* (*Item* 58 ÷ 25.)..... lbs.
69. *Equivalent evaporation from and at 212 degrees per pound of coal as fired.*† (*Item* 61 ÷ 25.)..... "
70. *Equivalent evaporation from and at 212 degrees per pound of dry coal.*† (*Item* 61 ÷ 27.)..... "
71. *Equivalent evaporation from and at 212 degrees per pound of combustible.*† (*Item* 61 ÷ 30.)..... "

(If the equivalent evaporation, Items 69, 70 and 71, is not corrected for the quality of steam, the fact should be stated.)

Efficiency.

(Art. XXI, Code.)

72. *Efficiency of the boiler; heat absorbed by the boiler per pound of combustible divided by the heat value of one pound of combustible*‡..... per cent.
73. *Efficiency of boiler, including the grate; heat absorbed by the boiler, per pound of dry coal, divided by the heat value of one pound of dry coal*..... "

Cost of Evaporation.

74. *Cost of coal per ton of——pounds, delivered in boiler room*.. $
75. Cost of fuel for evaporating 1,000 pounds of water under observed conditions..... $
76. *Cost of fuel used for evoporating* 1,000 *pounds of water from and at* 212 *degrees*..... $

Smoke Observations.

77. Percentage of smoke as observed..... per cent.
78. Weight of soot per hour obtained from smoke meter..... ounces.
79. Volume of soot per hour obtained from smoke meter..... cub. in.

* Held to be the equivalent of 30 pounds of water per hour evaporated from 100 degrees Fahrenheit into dry steam at 70 pounds gage pressure. (See Introduction to Code.)

† The symbol "U. E.," meaning "Units of Evaporation," may be conveniently substituted for the expression "Equivalent water evaporated into dry steam from and at 212 degrees," its definition being given in a foot note.

‡ In all cases where the word combustible is used, it means the coal without moisture and ash, but including all other constituents. It is the same as what is called in Europe "coal dry and free from ash."

Methods of Firing.

80. Kind of firing (spreading, alternate or coking).....
81. Average thickness of fire.....
82. Average intervals between firings for each furnace during time when fires are in normal condition.....
83. Average interval between times of levelling or breaking up

Analyses of the Dry Gases.

84. Carbon dioxide (CO_2).....	per cent.
85. Oxygen (O).....	"
86. Carbon monoxide (CO).....	"
87. Hydrogen and hydrocarbons.....	"
88. Nitrogen (by difference) (N).....	"
	100 per cent.

TABLE No. 2.—DATA AND RESULTS OF EVAPORATIVE TEST.

Arranged in accordance with the Short Form advised by the Boiler Test Committee of the American Society of Mechanical Engineers. Code of 1899.

Made by.....on.....boiler, at.....to determine.....
Kind of fuel.....
Kind of furnace.....
Method of starting and stopping the test ("standard" or "alternate," Art. X and XI, Code).....

Grate surface.....	sq. ft.
Water-heating surface.....	"
Superheating surface.....	"

Total Quantities.

1. Date of trial.....	
2. Duration of trial.....	hours.
3. Weight of coal as fired *.....	lbs.
4. Percentage of moisture in coal *.....	per cent.
5. Total weight of dry coal consumed.....	lbs.
6. Total ash and refuse.....	"
7. Percentage of ash and refuse in dry coal.....	per cent.
8. Total weight of water fed to the boiler*.....	lbs.
9. Water actually evaporated, corrected for moisture or superheat in steam.....	"
10. Equivalent water evaporated into dry steam from and at 212 degrees*.....	"

* See foot-notes of complete form.

Hourly Quantities.

11. Dry coal consumed per hour	lbs.
12. Dry coal per square foot of grate surface per hour	"
13. Water evaporated per hour corrected for quality of steam,	"
14. Equivalent evaporation per hour from and at 212 degrees*	"
15. Equivalent evaporation per hour from and at 212 degrees per square foot of water-heating surface*	"

Average Pressures, Temperatures, etc.

16. Steam pressure by gage	lbs. per sq. in.
17. Temperature of feed water entering boiler	deg.
18. Temperature of escaping gases from boiler	"
19. Force of draft between damper and boiler	ins. of water.
20. Percentage of moisture in steam, or number of degrees of superheating	per cent. or deg.

Horsepower.

21. Horsepower developed (Item 14 ÷ 34½)*	H.P.
22. Builders' rated horsepower	"
23. Percentage of builders' rated horsepower developed	per cent.

Economic Results.

24. Water apparently evaporated under actual conditions per pound of coal as fired. (Item 8 ÷ Item 3)	lbs.
25. Equivalent evaporation from and at 212 degrees per pound of coal as fired.* (Item 9 ÷ Item 3)	"
26. Equivalent evaporation from and at 212 degrees per pound of dry coal.* (Item 9 ÷ Item 5)	"
27. Equivalent evaporation from and at 212 degrees per pound of combustible.* [Item 9 ÷ (Item 5 — Item 6)], (If Items 25, 26 and 27 are not corrected for quality of steam, the fact should be stated.)	"

Efficiency.

28. Calorific value of the dry coal per pound	B.T.U.
29. Calorific value of the combustible per pound	"
30. Efficiency of boiler (based on combustible)*	per cent.
31. Efficiency of boiler, including grate (based on dry coal),	"

Cost of Evaporation.

32. Cost of coal per ton of —— pounds delivered in boiler-room	$
33. Cost of coal required for evaporating 1,000 pounds of water from and at 212 degrees	$

* See foot notes of Complete Form.

Appendix VII.

WEIGHING THE WATER.

The best way is to have two tanks capable of holding 1,200 to 1,800 pounds—say 20 to 30 cubic feet; or two weighing tanks and one feeding tank, 144 to 216 gallons, each placed on a pair of scales, to be filled and emptied alternately. To avoid suspicion of leakage of stop cocks, it is better to draw out the water by a flexible pipe or suction hose put alternately into the two tanks. The time of each weighing of each tank, to be designated as tank No. 1 and tank No. 2, should be accurately noted, and a method of checking the weighings by a diagram or chart, as in respect to the coal, should be adopted. J. C. H.

Appendix VIII.

MEASURING THE FEED WATER.

I would recommend that on all tests of any magnitude the water be fed to the boilers from a single tank of known capacity. That the tank be always filled so as to overflow, while the feed pump is stopped, and also the communication to it is closed.

That the inlet pipe shall terminate above the tank so that its orifice is always visible. That after the supply has been shut off, and the overflow has ceased, the communication to the feed pump be opened and the pump be started. That the water be drawn down to a point that is determined by a line on a graduated rod attached to a float that has been well painted so as not to absorb the water; and that then the pump be stopped, communication with it be closed, and the tank be refilled.

Appendix XI.

DETERMINING THE MOISTURE IN COAL.

Until recently two methods of determining moisture in coal have been in common use—first, the one usually adopted in boiler testing, which consists in drying a large sample, fifty pounds or more, in a shallow pan placed over the boiler or flue; second, the method usually followed by chemists of drying a one-gram sample of pulverized coal at 212 degrees Fahrenheit,

or a little above, for an hour, or until constant weight is obtained. Both methods are liable to large errors. In the first method, the temperature at which the drying takes place is uncertain, and there is no means of knowing whether the temperature obtained is sufficient to drive off the moisture which is held by capillary force or other attraction within the lumps of coal, which, at least in case of bituminous coals, seem to be as porous as wood, and as capable of absorbing moisture from the atmosphere. The second method is liable to greater errors in sampling than the first, and during the process of fine crushing and passing through sieves a considerable portion of the moisture is apt to be removed by air drying. In an extensive series of boiler tests made by the writer in the summer of 1896, it became necessary to find more accurate means of determining moisture than either of those above described. It was found that by repeated heating at gradually increasing temperatures from 212 degrees up to 300 degrees, or over, and weighing at intervals of an hour or more, that the weight of coal continually decreased until it became nearly constant, and then a very slight increase took place, which increase became greater on further repeated heatings to temperatures above 250 degrees. It has often been stated that if coal is heated above 212 degrees Fahrenheit volatile matter will be driven off; but repeated tests on seventeen different varieties of coal mined in western Pennsylvania, Ohio, Indiana, Illinois and Kentucky, invariably showed a gradual decrease of weight to a minimum, followed by the increase, as stated above, and in no single case was there any perceptible odor or other indication of volatile matter passing off below a temperature of 350 degrees. The fact that no volatile matter was given off was further proved by heating the coal in a glass retort and catching the vapor driven off in a bottle filled with water and inverted in a basin; the air displaced from the retort by expansion due to the heating displacing the water in the bottle. When the retort was cooled, after being heated to 350 degrees in an oil bath, the air thus expanded contracted, and returned from the bottle to the retort, leaving the bottle full of water, as at the beginning of the heating, showing that no gas

had been given off, except possibly such exceedingly small amount as might be absorbed by the water.

The method described in Section XV of the report was then adopted as the best available method of determining the moisture in these coals. Its accuracy was further checked by other methods, as follows: 1. A lump of Illinois coal which had been found by heating to 300 degrees to contain 14 per cent. of moisture was exposed to the air in a closet for two months, and it gradually reabsorbed from the atmosphere all the moisture that had been driven off. 2. Another sample of the same coal was placed in a dessicator with concentrated sulphuric acid, and it lost practically the same percentage of moisture in two months that was given off by the heating. 3. Seven other samples of different coals were similarly treated for six weeks, and all of them lost within about 1 per cent. of the amount that duplicate samples had lost by heating, and the difference in each case was lost by a single heating for an hour to 280 degrees.

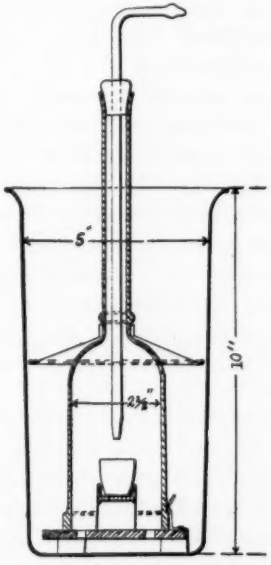
The new method of drying and its results were communicated by the writer to Professor R. C. Carpenter, of Cornell University, shortly after they were made, and he thereupon began experimenting with the method and fully confirmed the writer's conclusions. W. K.

Appendix XIII.

COAL CALORIMETER.

The coal calorimeter which the writer employs is that described in a paper on "A Coal Calorimeter," read at the Chicago meeting in 1893, and published in the "Transactions," Vol. XIV, p. 816. The details of the instrument are shown in the accompanying cut. It consists of a glass beaker 5 inches in diameter and 11 inches high, which can be obtained of most dealers in chemical apparatus. The combustion chamber is of special form, and consists of a glass bell having a notched rib around the lower edge, and a bead just above the top, with a tube projecting a considerable distance above the upper end. These have thus far been made by J. W. Staniford, 36 Hanover street, Boston, and they are inexpensive. The bell is 2½ inches inside

diameter, $5\frac{1}{2}$ inches high, and the tube above is $\frac{5}{8}$ inch inside diameter, and extends beyond the bell a distance of 9 inches. The base consists of a circular plate of brass, 4 inches in diameter, with three clips fastened on the upper side for holding down the combustion chamber. The base is perforated, and the under side has three pieces of cork attached, which serve as feet. To the center of the upper side of the plate is attached a cup for



BARRUS' COAL CALORIMETER.

holding the platinum crucible in which the coal is burned. To the upper end of the bell, beneath the bead, a hood is attached, made of wire gauze, which serves to intercept the rising bubbles of gas and retard their escape from the water. The top of the tube is fitted with a cork, and through this is inserted a small glass tube which carries the oxygen to the lower part of the combustion chamber. This tube is movable up and down, and to some extent sideways, so as to direct the current of oxygen to

any part of the crucible, and adjust it to a proper distance from the burning coal.

There is no patent on the instrument, and, with the above description, any one interested can, with a little trouble, secure an outfit on this plan. In addition to the apparatus here shown there is required a tank of oxygen, such as the calcium light companies furnish, scales for weighing water, and delicate balances for weighing coal, besides a delicate thermometer for taking the temperature of the water, and another for showing the temperature of the atmosphere. The former should be graduated to tenths of a degree Fahrenheit.

In the writer's work with the instrument the quantity of coal used for a test is one gram, and of water, 2,000 grams. In working out the heat units allowance is made for the specific heat of the calorimeter, either by calculation or by experiment. Radiation is allowed for by commencing the test with a temperature as many degrees below the atmosphere as the temperature rises above the atmosphere at the end of the test. When very smoky coals are used, the sample is mixed with a small proportion of anthracite of known calorific value; and when anthracite coal is used, a small percentage of bituminous coal is likewise mixed with it.

Samples of two bituminous coals submitted by Mr. Kent of the committee, one of which was a highly volatile coal, were tested in this instrument, and a sample of the same submitted to Mr. Henry J. Williams, of Boston, for analysis. The analyses gave the following results, based on dry coal:

	No. 1.	No. 2.
Carbon	71.84 per cent.	82.27 per cent.
Hydrogen	4.81 "	4.70 "
Nitrogen	1.58 "	1.56 "
Oxygen	13.98 "	5.34 "
Ash	6.74 "	4.93 "
Volatile sulphur	1.05 "	1.20 "
	100.00	100.00

The calorific values worked out from these analyses, and those given by the calorimeter, are presented in the following table,

the formula used for obtaining the total heat of combustion from the analyses being $145 \times C + 625 \times \left(H - \frac{O}{8}\right)$.

	Number.	B.T.U. Based on Dry Coal.	B.T.U. Based on Combustible.
Calorimeter	1	12,705	13,646
Analysis	1	12,323	13,208
Calorimeter	2	14,631	15,320
Analyses	2	14,452	15,197

It will be seen that in one case the two results agree within less than 1 per cent., and in the other case within about 3 per cent.

The writer has used this instrument for over seven years, and has tested over two hundred samples of coal with it. The results always seem consistent with one another, and they agree substantially with those obtained from reliable analyses in cases when these have been made. G. H. B.

APPENDIX XV.

DETERMINATION OF THE MOISTURE IN THE STEAM.

The throttling steam calorimeter, first described by Professor Peabody in the "Transactions," Vol. X, p. 327, and its modifications by Mr. Barrus, Vol. XI, p. 790; Vol. XVI, p. 617; and by Professor Carpenter, Vol. XII, p. 840; also the separating calorimeter designed by Professor Carpenter, Vol. XVII, p. 608; which instruments are used to determine the moisture existing in a small sample of steam taken from the steam pipe, give results, when properly handled, which may be accepted as accurate within 0.5 per cent. (this percentage being computed on the total quantity of the steam) for the sample taken. The possible error of 0.5 per cent. is the aggregate of the probable error of careful observation, and of the errors due to inaccuracy of the pressure gages and thermometers, to radiation, and, in the case of the throttling calorimeter, to the possible inaccuracy of the figure 0.48 for the specific heat of superheated steam, which is used in computing the results. It is, however, by no

means certain that the sample represents the average quality of the steam in the pipe from which the sample is taken. The practical impossibility of obtaining an accurate sample, especially when the percentage of moisture exceeds 2 or 3 per cent., is shown in the two papers by Professor Jacobus in "Transactions," Vol. XVI, pp. 448, 1017.

In trials of the ordinary forms of horizontal shell and of water-tube boilers, in which there is a large disengaging surface, when the water level is carried at least ten inches below the level of the steam outlet, and when the water is not of a character to cause foaming, and when in the case of water-tube boilers the steam outlet is placed in the rear of the middle of the length of the water drum, the maximum quantity of moisture in the steam rarely, if ever, exceeds 2 per cent.; and in such cases a sample taken with the precautions specified in Article XIV of the Code may be considered to be an accurate average sample of the steam furnished by the boiler, and its percentage of moisture as determined by the throttling or separating calorimeter may be considered as accurate within $\frac{1}{2}$ of 1 per cent. For scientific research and in all cases in which there is reason to suspect that the moisture may exceed 2 per cent., a steam separator should be placed in the steam pipe, as near to the steam outlet of the boiler as convenient, well covered with felting, all the steam made by the boiler passing through it, and all the moisture caught by it carefully weighed after being cooled. A convenient method of obtaining the weight of the drip from the separator is to discharge it through a trap into a barrel of cold water standing on a platform scale. A throttling or a separating calorimeter should be placed in the steam pipe, just beyond the steam separator, for the purpose of determining, by the sampling method, the small percentage of moisture which may still be in the steam after passing through the separator.

The formula for calculating the percentage of moisture when the throttling calorimetar is used is the following:

$$w = 100 \times \frac{H - h - k(T - t)}{L},$$

in which w = percentage of moisture in the steam, H = total heat, and L = latent heat per pound of steam at the pressure in the steam pipe, h = total heat per pound of steam at the pressure in the discharge side of the calorimeter, k = specific heat of superheated steam, T = temperature of the throttled and superheated steam in the calorimeter, and t = temperature due to the pressure in the discharge side of the calorimeter, = 212 degrees Fahrenheit at atmospheric pressure. Taking k=0.48 and t=212, the formula reduces to

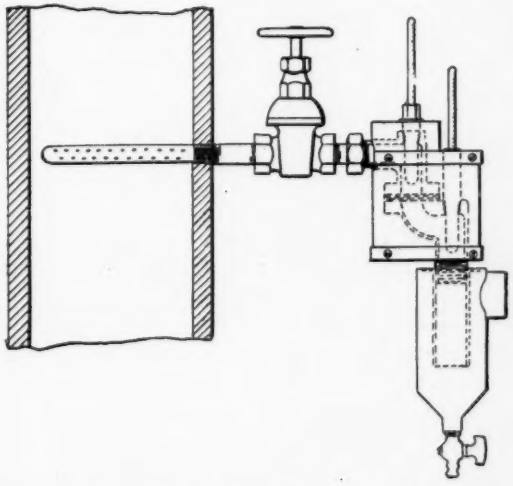
$$w = 100 \times \frac{H - 1146.6 - 0.48\,(T - 212)}{L}.$$

W. K.

Appendix XVII.

COMBINED CALORIMETER AND SEPARATOR.

The form of steam calorimeter which the writer uses is termed the "1895 pattern" universal steam calorimeter, and is a modifica-



tion of the one described in the "Transactions," Vol. XI, page 790. It is illustrated in the accompanying cut. It consists

of a throttling calorimeter and separator combined, the latter being attached to the outlet where the steam of atmospheric pressure is escaping. If the moisture is too great to be determined by the readings of the two thermometers, the separator catches the balance, and the total quantity of moisture is made up in part of that shown by the thermometers and in part of that collected from the separator. The percentage of moisture shown by the thermometers, is obtained by referring the indication of the lower thermometer to the normal reading of that thermometer with dry steam, and dividing the fall of temperature by the constant of the instrument for one per cent. of moisture. The normal reading is determined by observing the indications when steam in the main pipe is in a quiescent state, and the constant is a quantity varying from 21 degrees at 80 pounds pressure to 20 degrees at 200 pounds pressure. The percentage of moisture, if any, discharged from the separator, is found by dividing its quantity corrected for radiation, by the total quantity of steam and water passing through the instrument in the same time, as ascertained by experiment, and multiplying the result by 100. G. H. B.

APPENDIX XVIII.

CORRECTIONS FOR QUALITY OF STEAM.

Given the percentage of moisture or number of degrees of superheating, it is desirable to develop formulæ showing what we have termed "the factor of correction for quality of steam," or the factor by which the "apparent evaporation," determined by a boiler test, is to be multiplied to obtain the "evaporation corrected for quality of steam." It has been customary to call the proportional weight of steam in a mixture of steam and water "the quality of the steam," and it is not desirable to change this designation. The same term applies when the steam is superheated by employing the "equivalent evaporation," or that obtained by adding to the actual evaporation the proportional weight of water which the thermal value of the superheating would evaporate into dry steam from and at the temperature due to the pressure. "The factor of correction for quality of steam"

in a boiler test differs from the "quality" itself, from the fact that the temperature of the feed water is lower than that of the steam.

Let

Q = quality of moist steam as described above.

Q_1 = the quality of superheated steam as described above.

P = the proportion of moisture in the steam.

k = the number of degrees of superheating.

F = the factor of correction for the quality of the steam when the steam is moist.

F_1 = the factor of correction for the quality of the steam when the steam is superheated.

H = the total heat of the steam due to the steam pressure.

L = the latent heat of the steam due to the steam pressure.

T = the temperature of the steam due to the steam pressure.

T_1 = the total heat in the water at the temperature due to the steam pressure.*

J = the temperature of the feed water.

J_1 = the total heat in the feed water due to the temperature,*

Therefore, for moist steam:

(1) . . . . . $Q = 1 - P.$

(2) . . . . . $P = 1 - Q.$

(3) . . . . . $Q + P = 1.$

See also Equation (6).

With both the condensing and throttling calorimeters the water and steam are withdrawn from the boiler at the temperature of the steam, and with a separator the water can only be accurately measured when under pressure, so that the difference between the steam and the moisture in the steam, as they leave the boiler, is simply that the former has received the latent heat due to the pressure, and the latter has not. There is, however, imparted to the water in the boiler, not only the latent heat in the portion evaporated, but the sensible heat due to raising the temperature of all the water from that of the feed water to that of the steam due to the pressure.

* Most tables of the properties of steam and of water are based on the total heat of steam and water above 32 degrees Fahrenheit. For such tables the total heat in the water at a given temperature is equal approximately to the corresponding temperature minus 32 degrees. Exact values should, however, be taken from the tables.

In Equation (3) the proportional part Q receives from the boiler both the sensible and the latent heat, or the total heat above the temperature of the feed $= Q(H - J_1)$ thermal units, and the part P the difference in sensible heat between the temperatures of the steam and of the feed water $= P(T_1 - J_1)$ thermal units. If all the water were evaporated, each pound would receive the total heat in the steam above the temperature of the feed, or $H - J_1$. "The factor of correction for the quality of the steam," when there is no superheating, is therefore

$$(4) \quad . \quad F = \frac{Q(H - J_1) + P(T_1 - J_1)}{H - J_1} = Q + P\left(\frac{T_1 - J_1}{H - J_1}\right).$$

The superheating of the steam requires 0.48 of a thermal unit for each degree the temperature of the steam is raised; so for k degrees of superheating there will be $0.48k$ thermal units per pound weight of steam, and the "factor of correction for the quality of the steam" with superheating

$$(5) \quad . \quad . \quad . \quad F_1 = \frac{H - J_1 + 0.48k}{H - J_1} = 1 + \frac{0.48k}{H - J_1}.$$

See also Equation (7).

With the throttling calorimeter the percentage of moisture P, or number of degrees of superheating, are determined as explained in Appendix XV.

Since the invention of the throttling calorimeter the use of the original condensing, or so-called barrel, calorimeter is no longer warranted. Accurate results should, however, be obtained by condensing all the steam generated in the boiler, and this plan has been followed in certain cases. It has, therefore, been thought desirable to add other formulæ applicable to condensing calorimeters. The following additional notation is required:

$W =$ the original weight of the water in calorimeter, or weight of circulating water for a surface condenser.

$w =$ the weight of water added to the calorimeter by blowing steam into the water, or of "water of condensation" with a surface condenser.

t = total heat of water corresponding to initial temperature of water in calorimeter.

t_1 = total heat of water corresponding to final temperature in calorimeter.

Evidently then:

$W(t_1 - t)$ = the total thermal units withdrawn from the boiler and imparted to the water in calorimeter.

$\frac{W}{w}(t_1 t)$ = the thermal units per pound of water withdrawn from the boiler and imparted to the water in calorimeter, from which should be deducted $T_1 - t_1$ to obtain the number of thermal units per pound of water withdrawn from the boiler at the pressure due to the temperature T.

Since only the latent heat L is imparted to the portion of the water evaporated, the quality Q, or proportional quantity evaporated, may be obtained by dividing the total thermal units per pound of water abstracted at the pressure due to the temperature T by the latent heat L. Hence, as given in Appendix XVII, 1885 Code, with some differences in notation:

$$(6) \quad . \quad . \quad . \quad Q \text{ and } Q_1 = \frac{1}{L}\left[\frac{W}{w}(t_1 - t) - (T_1 - t_1)\right].$$

The value Q applies when the second term is less than unity. P may be derived therefrom by substitution in Equation (2) and F from Equation (4).

Q_1 applies when the second term of the above equation is greater than unity, which shows that the steam is superheated, and, as in this case, the heating value of the superheat has already been measured by heating the water of the calorimeter; the proportional thermal value of the same, in terms of the latent heat L, is represented directly by $Q_1 - 1$, and we have as the factor of correction for the quality of the steam with superheating:

$$(7) \quad . \quad . \quad F_1 = \frac{H - J_1 + L(Q_1 - 1)}{H - J_1} = 1 + \frac{L(Q_1 - 1)}{H - J_1}.$$

See also Equation (5).

When the quality is greater than 1, or equals Q_1, the number of degrees of superheating:

$$(8) \quad . \quad . \quad . \quad k = \frac{L(Q_1 - 1)}{0.48} - 2.0833L(Q_1 - 1).$$

C. E. E.

Appendix XIX.

THE QUALITY OF SUPERHEATED STEAM.

The quality of the superheated steam is determined from the number of degrees of superheating by using the following formula:

$$Q = \frac{L + 0.48(T - t)}{L},$$

in which L is the latent heat in British thermal units in one pound of steam of the observed pressure; T the observed temperature, and t the normal temperature due to the pressure. This normal temperature should be determined by obtaining a reading of the thermometer when the fires are in a dead condition and the superheat has disappeared; this temperature being observed when the pressure as shown by the gage is the average of the readings taken during the trial. Observations being made by the same instrument, errors of gage or thermometer are practically eliminated. G. H. B.

Appendix XXIV.

STEAM UNITS.

All measurements of the quantity of heat are based on the *thermal unit*, which, for British measures, equals the quantity of heat required to raise the temperature of one pound of pure water at or near its freezing point one degree Fahrenheit.*

The unit commonly used to express the evaporative power of the fuel is the quantity of heat required to evaporate one pound

* Compare "Rankine on Steam Engine," Art. 208; "Porter on the Richards Indicator," p. 43.

of water at a temperature of 212 degrees under the ordinary pressure of the atmosphere corresponding to that temperature. This was called by Rankine a "peculiar thermal unit," and its value given at 966.1 British thermal units, but has since been called the "*unit of evaporation*," which term is adopted in the foregoing general report of the committee. Its value, however, in the prominent American tables is given at 965.7 thermal units.

Appendix XXVII.

PYROMETER.

So far as known to me, the only way to measure temperatures between 600 or 700 degrees Fahrenheit, or above the range of the air thermometer, and 2,500 or 2,700 degrees Fahrenheit, or up to the melting point of commercial platinum, is by the platinum water pyrometer.

One form of this pyrometer is described in the "Journal of the Franklin Institute," Vol. LXXXIV, pp. 169 and 252, September and October, 1882. J. C. H.

PYROMETER.

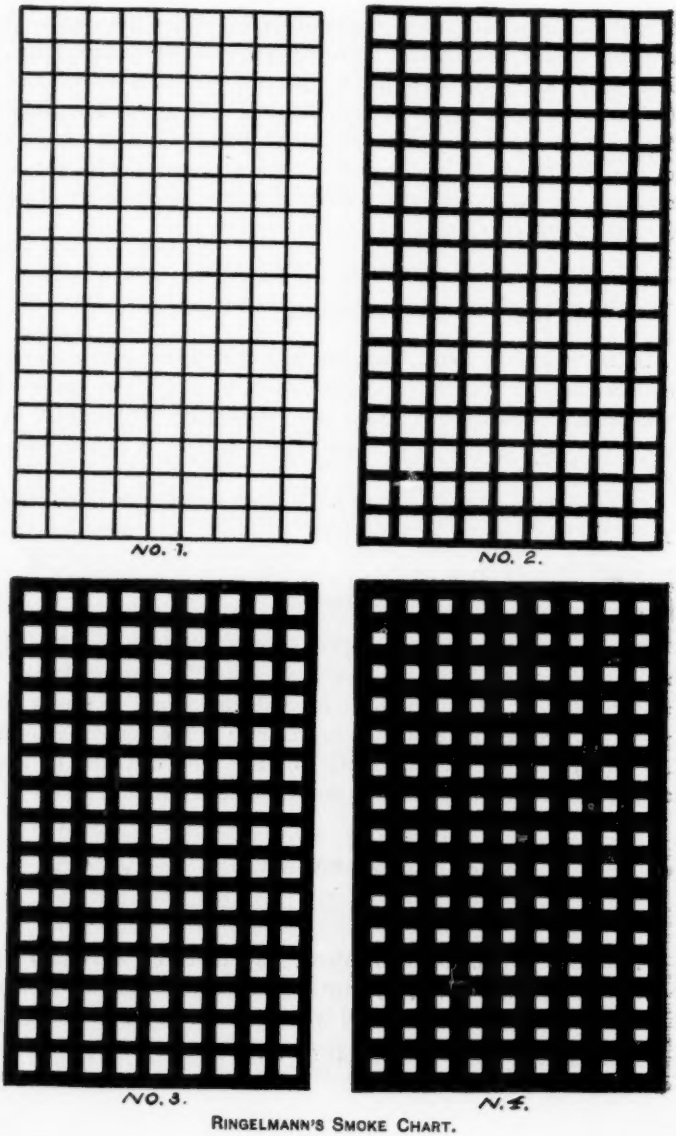
The temperature of the escaping gases should be ascertained, not by pyrometers, but by means of certified mercury thermometers introduced at a number of different points in the same plane transverse to the flue. The velocity of the current should be ascertained at each of these points. The distance of the transverse plane of observation from the boiler should be noted.

C. T. P.

Appendix XXXV.

THE RINGELMANN SMOKE CHART.

Professor Ringelmann, of Paris, has invented a system of determining the relative density or blackness of smoke, which has been communicated to the writer by Mr. Bryan Donkin, of London, and published in "Engineering News" of November 11, 1897. In making observations of the smoke proceeding from a



RINGELMANN'S SMOKE CHART.

chimney, four cards ruled like those in the cut, together with a card printed in solid black and another left entirely white, are placed in a horizontal row and hung at a point about 50 feet from the observer, and as nearly as convenient in a line with the chimney. At this distance the lines become invisible, and the cards appear to be of different shades of gray, ranging from very light gray to almost black. The observer glances from the smoke coming from the chimney to the cards, which are numbered from 0 to 5, determines which card most nearly corresponds with the color of the smoke and makes a record accordingly, noting the time. Observations should be made continuously during say one minute, and the estimated average density during that minute recorded, and so on, records being made once every minute. The average of all the records made during a boiler test is taken as the average figure for the smoke density during the test, and the whole of the record is plotted on cross-section paper in order to show how the smoke varied in density from time to time. A rule by which the cards may be reproduced is given by Professor Ringelmann as follows:

Card 0—All white.

Card 1—Black lines 1 mm. thick, 10 mm. apart, leaving spaces 9 mm. square.

Card 2—Lines 2.3 mm. thick, spaces 7.7 mm. square.

Card 3—Lines 3.7 mm. thick, spaces 6.3 mm. square.

Card 4—Lines 5.5 mm. thick, spaces 4.5 mm. square.

Card 5—All black.

The cards as printed here are of course much smaller than those actually used, but the spacing and thickness of the lines are proper. W. K.

Appendix XXXVI.

STARTING AND STOPPING A TEST.

Of the two methods of starting and stopping a test, the so-called "standard" method and the "alternate" method, the writer prefers the latter, believing that the errors in the estimation of the quantity and condition of the small amount of coal left on the grate after cleaning are less than the errors of the "standard"

method, which are due: first, to cooling of the boiler at the beginning and end of the test; second, to the imperfect combustion of the fuel at the beginning; and, third, to excessive air supply through the thin fire while burning down before the end of the test.

A special caution is needed against a modification of the "alternate" method, which has been adopted by some testing engineers within the past few years. It consists in taking the starting and the stopping times each at a time subsequent to the cleaning, say after 400 pounds of coal has been fired since the cleaning. There are two sources of serious error in this method, one causing an incorrect measurement of the coal, the other an incorrect measurement of the water. Suppose 200 pounds of hot coke are left on the grate at the end of cleaning and 400 pounds of fresh coal are added by the end of, say, half an hour after cleaning. If the coal left at the end of the cleaning, and the boiler walls also, are very hot, and the coal is highly volatile and dry and the pieces of such size as not to choke the air supply, the fire may burn so briskly that at the end of the half-hour the fuel value of the partly burned coal left out of the total 600 pounds is equivalent only to 200 pounds of coal. If, on the contrary, the hot coke on the grates at the end of the cleaning, and the boiler walls, are considerably cooled, if the fresh coal fired is moist and of small size, such as the slack of run-of-mine bituminous coal, which is often found in one portion of a pile in greater quantity than in another, the fire during the half-hour may burn so sluggishly that the coal and coke on the grate at the end of the half-hour may have a fuel value equal to 400 pounds of coal. If, in this case, it is assumed that the quantity and condition of the coal at the end of the half-hour after cleaning are the same at the starting and stopping time; and, if the fire burned briskly during the half-hour before starting and slowly during the half-hour before stopping, the boiler will be charged with more coal than was actually burned. If, on the contrary, the coal burns away more slowly during the half-hour after the cleaning before the starting time and more rapidly during the

half-hour before the end of the test, the boiler is not charged with as much coal as was actually burned.

The error in water measurement is due to the fact that the condition of the fire, and especially the quantity of flaming gases arising from it, influences the height of the water level. A bright hot fire, or a fire with an abundance of burning gas proceeding from it, causes the water level to rise; while anything that cools the furnace, such as freshly fired coal, an open fire door, or a check to the draft, causes the water level to fall. A rise or a fall of several inches in a few seconds frequently occurs when bituminous coal is used. If the water level is noted at the starting of the test, when it is raised by a bright fire, and at the end of a test, when it is depressed by the stoppage of violent ebullition or of rapid circulation, due to the cooling of the fire, the boiler will be credited with more water than was really evaporated, and *vice versa*.

The only correct times to be noted as the starting and the stopping times are when the smallest amount of fuel is on the grate, and when it is in the most burned-out condition; that is, just before firing fresh coal after cleaning, and when the water level is in its most quiet condition and the least raised by ebullition; that is, after the furnace door has been kept open for some time for cleaning and the furnace, therefore, is in its coolest state. This condition of fire and of water level can be duplicated immediately after cleaning the fire; but there is no certainty of duplication of any condition when there is a bright fire and consequent rapid steaming.

These statements are not based upon theoretical considerations, but are the results of many experiments made by the writer to determine the best starting and stopping times. In a long series of tests with bituminous coals no less than six different times were recorded as starting times and as many as stopping times, and the coal apparently used and the water apparently evaporated recorded and calculated for each. These times were: *A*, before opening the first or right-hand door to clean the fire; *B*, after cleaning the first half of the furnace and just before firing fresh coal; *C*, after cleaning the second half of

the furnace; *D*, after 200 pounds of fresh coal had been fired; *E*, after 400 pounds; *F*, after 600 pounds. By plotting the apparent water evaporation between *A* and *E*, both for starting and for stopping times, it was seen that there was nearly always an apparent negative evaporation between *B* and *D*, and sometimes between *B* and *C* and between *B* and *E*, due to the correction for height of observed water level, the level rising rapidly, being much greater than the water fed by the pump. There was often no similarity of appearance of the plotted diagrams between *A* and *F* at the beginning and at the end of the same test. The possible error of water measurement due to taking *A*, *D*, *E* or *F* as the starting time was sometimes as much as 2,000 pounds of water, or about 3 per cent. of the whole amount evaporated in a ten-hour test. The record of water evaporated between the stopping and starting times *C* occasionally differed considerably from that taken between the *B* start and stop, due to the fact that sometimes between *B* and *C* there was a sudden lighting up of the fresh coal on the cleaned side of the furnace, while at other times the fire would not light up brightly until after the *C* point had passed. It was therefore decided that the *B* time, when the furnace was the coldest and the water level at the lowest, was the only time which could be accepted as the true starting and stopping time. W. K.

PROGRESSIVE TRIALS OF THE ITALIAN TORPEDO BOAT *CONDOR*.

TRANSLATED BY W. F. DURAND FROM "REVISTA MARITTIMA."

During the month of June last a series of trials were made, near Genoa, of the Italian seagoing torpedo boat *Condor*. This boat was built in the yards of the Ansaldo Company at Sampierdarena, from plans developed by Engineer Count Rota, of the Italian Navy.

The principal dimensions of the *Condor*, which is armed with two swiveling torpedo tubes, located near the extremities of the deck, and with two 37-millimeter guns in the conning towers, are as follows :*

Length between perpendiculars, feet	154
Greatest beam, feet and inches	18–3
Depth of hull, feet and inches	10–6
Draught at stern, aside from propellers and rudder, feet and inches	4–6
at bow, feet and inches	3–6
mean, feet	4
Displacement (tons)	137

Hull.—The hull is constructed of Siemens-Martin steel, the plates and shapes being galvanized. By means of transverse watertight bulkheads the boat is divided into twelve watertight compartments. In addition, there is a watertight flat worked at about twenty-seven inches above the keel, which forms a double bottom, and thus adds to the safety of the boat. On either side of the boilers are fitted watertight longitudinal bulkheads, the compartments thus formed serving for coal bunkers in case the adoption of liquid fuel should be much delayed.

The forward tower is constructed of nickel-steel plate $\frac{1}{2}$-inch in thickness.

* The data given throughout the article are translated into English measures, except in the case of *horsepower*. The difference here is but slight (1 metric horsepower = .986 English horsepower), and in order to correspond with the diagrams reproduced from the original, the metric values are retained.

The double bottom is utilized for carrying oil fuel and also water for drinking or for use in the boilers.

The accompanying figures show schematically the structure of the hull and the subdivision of the various parts of the boat.

The leading features of the machinery are as follows:

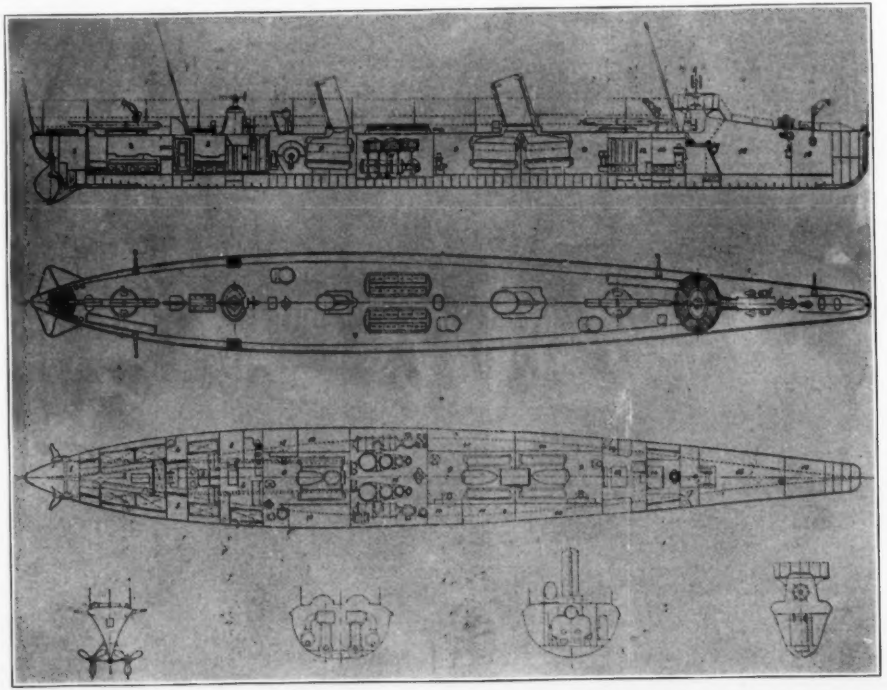
Number of engines	2
Diameter of cylinders, inches	15¾, 24¾, 35½
Stroke, inches	15¾
Number of boilers, type, Yarrow	3
Height, feet and inches	7–10
Width, feet and inches	8– 2
Length, feet and inches	10– 2
Number of furnaces per boiler	1
Length of grate, feet and inches	6–10
Width of grate, feet and inches	4–11
Grate surface, total, square feet	102
Heating surface, square feet	4,844
Evaporating surface, square feet	74
Volume of steam in upper drum, cubic feet	94
Volume of water in upper drum, cubic feet	173
Working pressure, pounds	200
Diameter of the propellers, feet and inches	5–11
Pitch (uniform), feet and inches	8–10
Number of blades on each	3

WEIGHTS.	Tons.
Shafting, propellers, struts, etc.	4.27
Main engines and auxiliaries	23.76
Boilers, funnels and piping	21.00
Water in boilers	5.59
Spare parts, stores, etc.	3.83
Total	58.45

INCLINING EXPERIMENTS AND STABILITY.

Accurate inclining experiments, which were carried out in a large basin at Genoa gave the following results relating to the stability of the *Condor:*

Displacement at deep normal load, tons	137.6
Mean draught, feet	4
Metacentric height ($\rho - a$), feet	1.97
Range of positive stability, degrees	107
Angle of maximum stability degrees	55
Period of a single oscillation (from one side to the other), seconds	2½



ITALIAN SEA-GOING TORPEDO BOAT "CONDOR."

In the unloaded condition the general stability characteristics are practically the same.

SEA TRIALS.

The trials prescribed in the contract for the construction of the boat were as follows:

(1) A trial of six hours duration with natural draft, the ventilators being so adjusted as to produce a draft corresponding to a column of water of about one-half inch. The engines were to develop in this trial not less than 1,800 I.H.P. with the use of liquid fuel, or 1,000 I.H.P. in case coal were used.

(2) A trial of three hours duration with forced draft, the air pressure not to exceed three inches of water. Under these conditions the engines were to develop not less than 2,400 I.H.P.

It having been decided that liquid fuel should not be used in these trials, they were carried out by the use of coal alone.

The system of forced draft adopted for the boilers of the *Condor* and prescribed in the contract was the so-called "closed ash-pit" system. After a series of preliminary trials carried out for the purpose of training the fire-room force, it became apparent that no matter how skillful the firemen might be, it was not practicable at the highest speeds to obtain a regular production of steam, and that whenever the revolutions were notably increased, water was to some extent carried over from the boilers to the cylinders. The six-hour trial with natural draft was, however, carried out with regularity and success.

Following are the results of this trial:

Mean draft, feet	4
speed for the duration of the trial	20.8
Indicated horsepower	1,157
Revolutions (average for the entire trial)	258
Condition of the sea	moderate swell.
wind	fresh.
Pressure of air in the ash pits, measured in inches of water	.5
Steam pressure at boilers, pounds per square inch	175
in steam pipe, pounds per square inch	174
Vacuum in condenser, inches of mercury	28
Stop-valve opening	.5
Throttle-valve opening	.7

Consumption of coal per I.H.P per hour, pounds	2.66
Combustion per square foot grate surface, pounds	30
Total coal per hour, pounds	3,042
Temperature in boiler-room, degrees Fahrenheit	115
engine-room	109

It having been ascertained that the cause of the irregularity in the production of steam at speeds higher than that obtained on this trial was due to the method of forced draft with jets of air led into the ash pits, a change of arrangement was effected through the disposition of the ventilators in such manner that the necessary draft was assured by the forcing of air into the fire rooms.

With this arrangement the troubles experienced with the first system were entirely avoided, and the full-power trials were carried out with brilliant success.

Following are the results for the full-power trial of three hours' duration:

Mean draft, feet and inches	4–1
speed	25.7
Maximum speed observed	26.3
Condition of the sea	moderate swell.
wind	light.
Indicated horsepower	2,410
Revolutions (mean for the trial)	341
Pressure of air in the fire rooms, measured, in inches of water (mean)	1.7
Steam pressure in boilers (mean)	196
steam pipe	173
Vacuum in the condenser in inches of mercury (mean)	25.75
Opening of stop and throttle valves	full.
Temperature of fire-rooms, degrees Fahrenheit	106
engine-room, degrees Fahrenheit	106
Quality of coal	selected Cardiff.
Consumption of coal per I.H.P. per hour, pounds	2.71
Combustion per square foot of grate surface, pounds	62
Total coal burned per hour, pounds	5,028

The results of this trial are noteworthy in that without hard forcing and with an air pressure of less than *two* inches of water instead of the *three* inches allowed by the contract, the full designed power of 2,400 I.H.P. was obtained.

During the trial the vibrations were scarcely noticeable, a

noteworthy result due in part to the special structure of the hull, but chiefly to the smooth operation of the engines, the balancing of which had been made a special study by Engineer A. Perroni, their designer. The entire motive equipment gave no trouble whatever, and with the above-mentioned change in the method of forced draft the troubles previously met with in connection with the fires were entirely avoided.

After the full-power trial, a second natural-draft trial was made with an air pressure of one-half inch of water in order to compare with the previous results, and to note what advantage in these conditions might arise from the change in the method of forced draft as described above. The results showed a marked advantage, 1,500 I.H.P being developed with 285 revolutions, giving a speed of about 22 knots, instead of 20.8. It was also found that the consumption of coal per I.H.P. per hour was reduced to 2.16 pounds.

PROGRESSIVE TRIALS.

After the trials referred to above, a further series of progressive trials was carried out for the purpose of establishing the relations between the three elements, revolutions, speed and indicated horsepower. Previous trials had been carried out in the Froude tank at Spezia on a model of the boat, and a comparison of the two sets of results will serve to furnish the most valuable deductions regarding the efficiency of the propulsive equipment. To this end use is made as well of the results obtained from the preceding trials of the boat, all of which are collected and shown in plate I.

The abscissa gives the number of revolutions per minute, the upper curve the speed and knots, and the lower curve the I.H.P. In plate II the abscissa gives the speed in knots, and the upper curve the revolutions per minute.

Next below is given the curve of indicated horsepower (F.C.I.) and below that the curve of effective horsepower (F.C.E.) The latter values are derived directly from the tank experiments referred to above. The curve of propulsive efficiency, or ratio of

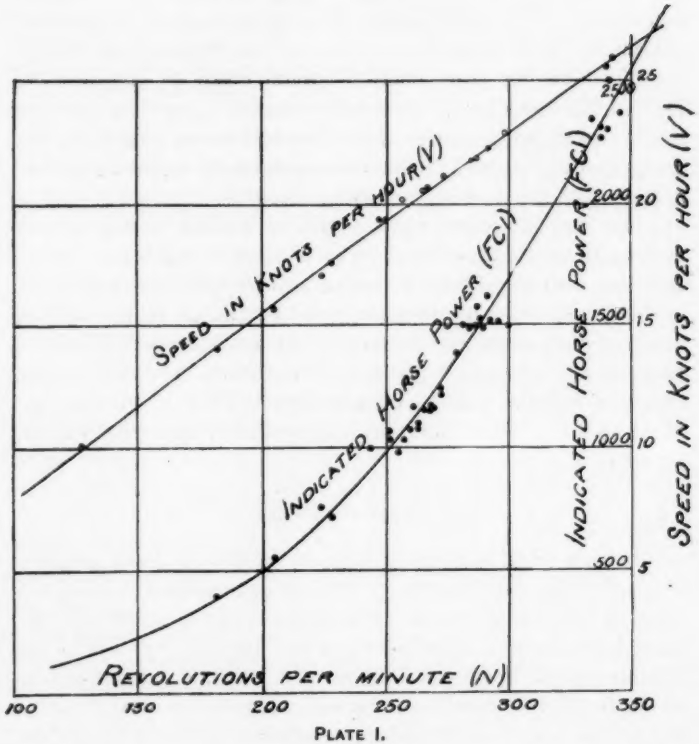


PLATE I.

effective to indicated horsepower, (F.C.E. ÷ F.C.I.) is shown in the sinuous curve running across the diagram.

The Italian lettering in brackets has been preserved for the indications of power, speed, etc., on curves, the equivalent English expression being used in connection therewith, these curves being copied directly from the plates in the Italian review.*

It appears that the highest value (.649) of the propulsive coefficient is reached at a speed of 21 knots, corresponding to the

* On the efficiency curve itself the lettering within the brackets is wrong, but is correct in the text.

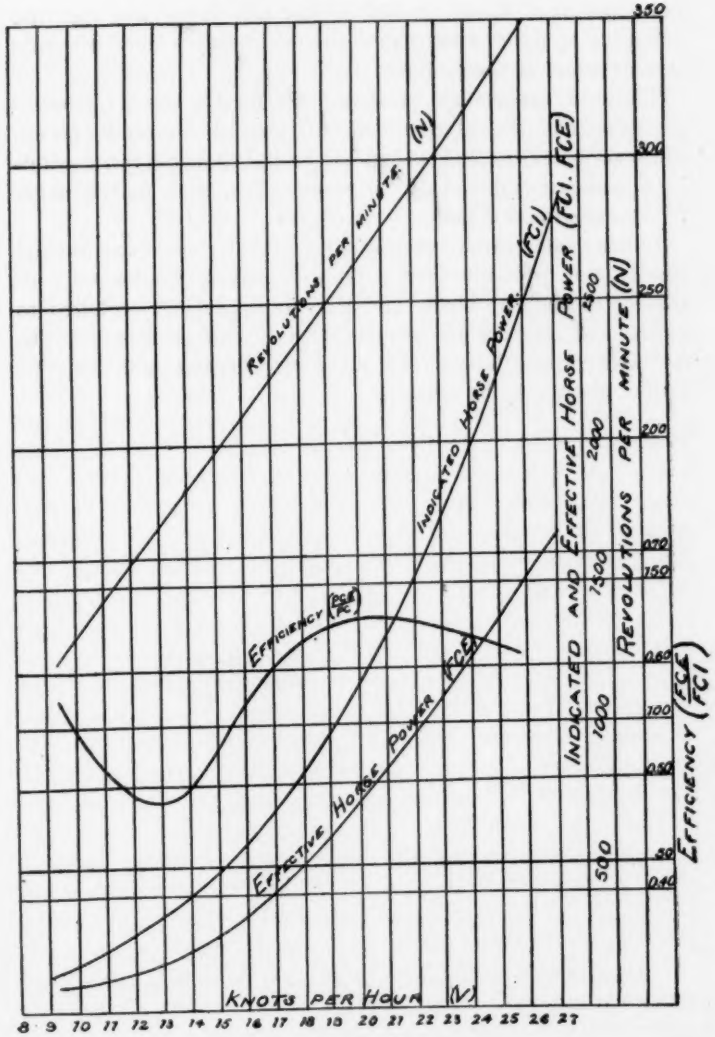

REVOLUTIONS PER MINUTE (N)
INDICATED HORSE POWER (FCI)
EFFICIENCY (ECE/FCI)
EFFECTIVE HORSE POWER (ECE)
INDICATED AND EFFECTIVE HORSE POWER (FCI. ECE)
REVOLUTIONS PER MINUTE (N)
EFFICIENCY (ECE/FCI)
KNOTS PER HOUR (V)
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
350 300 250 200 150 100 50
2300 2200 2100 2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500
070 060 050 040 030

PLATE II.

development of about one-half of the full power, and that the efficiency at higher speeds up to the maximum of about 26 knots is maintained at values above .60.

These indications are most valuable for the study of similar problems, and their determination is possible simply by reason of the progressive trials carried out on the boat, and the possibility of comparing them with the results of the trials on the model in the experimental tank.

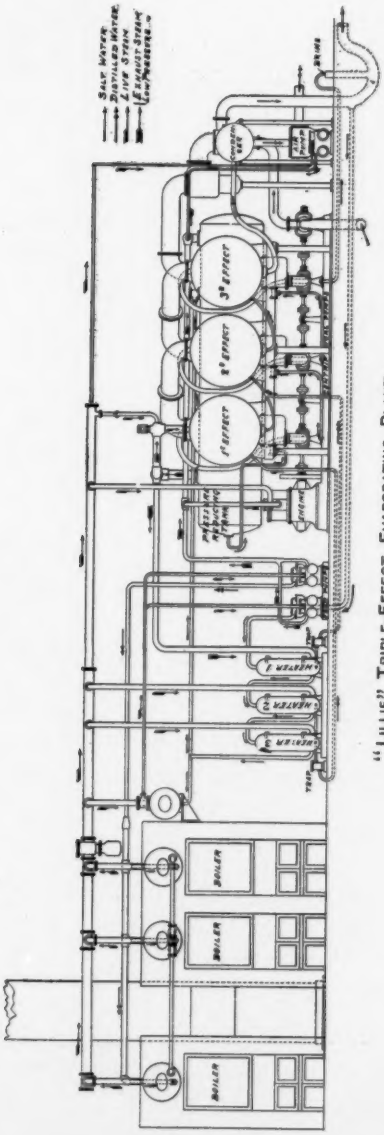
In conclusion it may be pointed out that these experimental results may properly inspire us with strong confidence with respect to such problems, and if every opportunity is taken to collect and compare the results of trials with models and with full-sized vessels, information of the very highest value for their further study may be derived.

REPORT OF A SIX-DAY TRIAL OF THE "LILLIE" MULTIPLE-EFFECT DISTILLING PLANT AT DRY TORTUGAS, JANUARY 18 TO 20, 1900.

By Lieutenant R. K. Crank, U. S. N.

This plant was erected for the Navy Department by The Sugar Apparatus Manufacturing Company of Philadelphia, after designs by S. Morris Lillie, President of the Company, and under his patents.

The method followed in this "multiple-effect" system is, briefly, as follows: the sea water to be evaporated is first passed through heaters which are supplied with steam from the boilers or from the pressure-reducing tank. The temperature of the sea water is raised to about 300 degrees or more in the heaters. The heated sea water then passes to a pressure-reducing tank, in which a pressure of from 10 to 15 pounds is maintained. A portion of the water becomes steam on account of the low pressure and high temperature. The exhaust steam from all the auxiliary machinery of the plant also goes into this tank. The steam from the pressure-reducing tank is almost all employed to heat the first heater through which the sea water is passed. The unevaporated portion of the sea water in the tank then goes into the first effect (or evaporator), passing first through a centrifugal circulating pump, by which it is showered over the outside of the evaporating tubes. Live steam from the boilers, supplemented by steam from the pressure-reducing tank, is admitted to the inside of the evaporating tubes. A portion of the sea water is converted into steam; this steam passes into the evaporating tubes of the next lower effect, where it aids in evaporating the salt water in that effect. The unevaporated portion of the sea water falls to the bottom of the first effect, whence it is drawn by the centrifugal pump and again showered



"LILLIE" TRIPLE-EFFECT EVAPORATING PLANT.

over the evaporating tubes of this effect, the loss from evaporating being automatically supplied, through a float valve, by fresh feed from the pressure-reducing tank. This action is continued in each of the effects, the constantly moving sea water increasing in density as it passes in turn through the effects. In the last effect, the brine is drawn off at any desired density at a temperature corresponding to the very low pressure (below atmospheric pressure) maintained in this effect. In an ordinary "single-effect" evaporator, such as is used aboard ship, the brine is blown off at a comparatively high temperature and much heat wasted.

The plant at Tortugas consists of:

1. Three Babcock & Wilcox boilers, of 125-horsepower each, built to carry 160 pounds pressure per square inch.

2. One "Lillie" triple-effect, comprising three effects, or evaporators, with surface condenser 30 inches in diameter and 12 feet long, with duplex vacuum pump (air pump) 9 inches by 12 inches by 10 inches, for maintaining vacuum in third effect, and for condensing vapors for same; four centrifugal, circulating pumps, one for each effect and one for the condenser, all four on one shaft driven by a directly-coupled Westinghouse 8-inch by 8½-inch engine.

3. Three Blake duplex, double-plunger feed pumps, of which two are 7½ inches by 4 inches by 6 inches, and one 7½ inches by 4½ inches by 10 inches, which may be used to feed boilers or to force sea water through heaters.

4. Three pipe heaters for heating the sea water, each provided with a trap for trapping the condensed steam from the heaters.

5. One pressure-reducing tank, fitted with float valve for regulating the flow of salt water into it from heaters.

6. Two automatic regulating valves and tanks, respectively for regulating feed to boilers and feed of sea water to the plant. Only one appears in the plan.

The effects or evaporators are peculiar and important parts of the apparatus. As will be seen from Figure No. 1, the evaporating tubes open into a steam chamber in the back end of the effect. These tubes are not horizontal, but are slightly inclined,

the ends in the tube sheets and nearer the steam chamber being the lower; these lower ends are expanded in a heavy tube sheet, which is about 3 inches in thickness. The other ends are closed

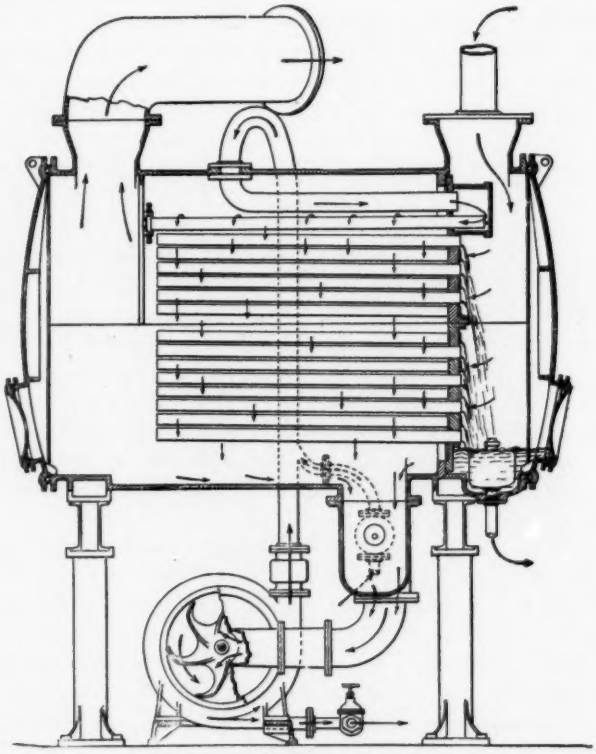


FIG. 1.

by a slightly tapered plug; this plug is driven in and the end of tube then "crimped" over and soldered. A small air vent (about $\frac{1}{32}$ inch in diameter,) is bored in the plug. This vent allows the air or other gases that enter with the steam or may be given off by the liquid that is being evaporated to escape. It has been found that where no vent has been provided, the gases

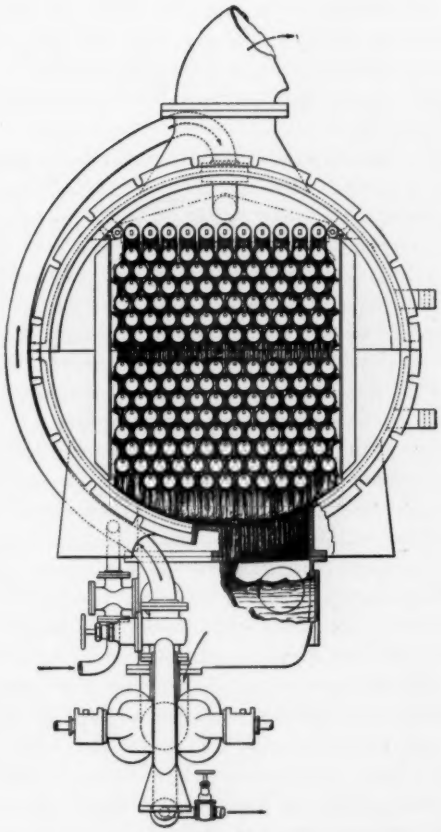


FIG. 2.

and air soon accumulate in the end of the tubes and greatly reduce their evaporating power by preventing the entrance of the steam. The closed end of the tube is unsupported. Thus the tubes are perfectly free to expand on change of temperature. There is no circulation of the steam in and through the tubes, as in the Navy evaporators. Each effect contains 106 of these tubes. The tubes are of copper, seamless-drawn, 3 inches in diameter, and 5 feet and $2\frac{1}{2}$ inches in length. The tubes are staggered. (See Fig. No. 2.)

Above these evaporating tubes there is a row of sea-water distributing tubes, each having a narrow, longitudinal slot along its upper surface. The front ends of these tubes are closed. The back ends open into a manifold box on the upper part of the tube sheet. Above, below and on each side of the evaporating tubes is a vapor space, extending from the tube sheet to the front vapor space (marked in the figures, 1 and 2). On the under side of the evaporator shell there is a well or a float box to which the suction pipe of the centrifugal circulating pump is connected. The three circulating pumps of the effects and the condenser circulating pump are all on one line of shafting and are run by the same engine.

When the effect is in operation, the steam (live, or exhaust, or vapor from a hotter effect) enters the steam chamber and passes into the evaporating tubes; this steam is condensed by and causes evaporation from the sea water which is being circulated or showered over the outside of the tubes by the circulating pump, through the distributing tubes at the top. The water of condensation in the evaporating tubes flows, by gravity, back into the steam chamber, from the bottom of which it runs through a trap and pipe into the steam chamber of the next lower effect, where, on account of the lower pressure in this next lower effect, it at once vaporizes (in part) and the resulting vapor assists in the evaporation of the salt water in this effect.

A portion of the salt water showered over the evaporating tubes is vaporized, and this vapor passes through a large vapor pipe, or exhaust pipe, into the *steam chamber* of the next lower effect, where it is used to evaporate the salt water in this next

lower effect. The remainder of the salt water falls to the bottom of the shell of the effect and into the float box or well, whence it is drawn by the circulating pump, to be again showered over the evaporating tubes (only a thin film of the liquid being in contact with the tubes), which with the constant circulation and the easy separation of the vapor from the liquid and the "film evaporation" is a peculiar feature and advantage of this system.

The circulating pump of each effect has a 2-inch discharge pipe. The discharge pipe of each pump leads to the float box of the next lower effect. The discharge pipe of the last effect leads into the air, and from this last discharge pipe the discharged brine passes off. The density of this brine is regulated by the amount of opening of the discharge valve. The salt-feed supply to the first effect (from the pressure-reducing tank) enters this first effect through a balanced valve, which is controlled by a float in the float box of this effect. This valve maintains the salt water in the effect at a constant level. Now, since the discharge from each effect is the feed to the next lower effect, the amount of feed water that passes from the third effect (as vapor to the condenser and as discharged brine) determines the amount of sea water that is admitted from the second (or next higher) effect to the third; and this water that passes from the second effect to the third is replaced by the discharge from the first effect, which, in a similar manner, is replaced by fresh feed from the pressure-reducing tank, entering through the automatic float valve of the first effect.

The sea water is thus constantly passing through the effects, being circulated in each, its density increasing as it passes from one effect to the next lower. Thus, the level of the sea water in each effect, the amount of feed admitted to the first effect from the tank, the movement of the sea water from effect to effect, are all (automatically) determined by the opening of the discharge valve of the circulating pump of the third effect.

This triple-effect portion of the plant was built originally for concentrating sugar solutions, and had been actually erected in a sugar refinery. The contract for supplying and erecting the plant was made during the war with Spain and was a hurry

order. As this was the only "Lillie" triple effect immediately available, it was used, by permission of the Department, in filling the contract. Its construction would have been slightly different had it been built purposely for distilling sea water.

The pressure-reducing tank serves as a receiver for the heated salt water that comes from the heaters at a temperature of over 300 degrees. If this heated water were sent directly to the first effect, much of it would at once vaporize at the low pressure in this effect, and would pass directly to the second effect as vapor. This vaporization, however, takes place in the tank. As the volume of water in the tank is large in comparison with the amount passing to the first effect as feed, and hence is not in rapid motion, some of the solid matter in the sea water (salts that are insoluble at the high temperature above 300 degrees) has time to settle and is blown off; the pressure maintained in the tank varies from 10 to 15 pounds above atmosphere. From one end of the tank (below the lowest water level) a feed pipe leads to the automatic valve in the float box of the first effect. From the top of the tank the steam (exhaust from the pumps and steam from the heated salt water) passes through a pipe partly to the steam chamber of the first effect. The greater part of the steam formed in the tank is used, however, for heating in the first or low-pressure heater. Live steam from the boilers is also admitted through a 2-inch steam pipe to the steam chamber of the first effect. This is the only boiler steam that is admitted to the effects. The condensation from the traps of the second and third (or high-pressure) heaters also goes into the steam chamber of the first effect. The condensation from the first or low-pressure heater goes into the steam chamber of the second effect.

The heaters (see Fig. No. 3) each contain 20 wrought-iron steam tubes, 4 inches in diameter by 9 feet in length. Passing through each iron steam tube there is a 3-inch copper water-tube, 10 feet 10 inches in length, secured at its outer ends in outer tube sheets. The water enters the tubes at the top of the heater and flows back and forth through each of the water tubes, traveling 108 feet in its passage. The steam for heating is in

the annular space between the steam and water tubes. In the second and third (or high-pressure) heaters, this steam comes from the boilers.

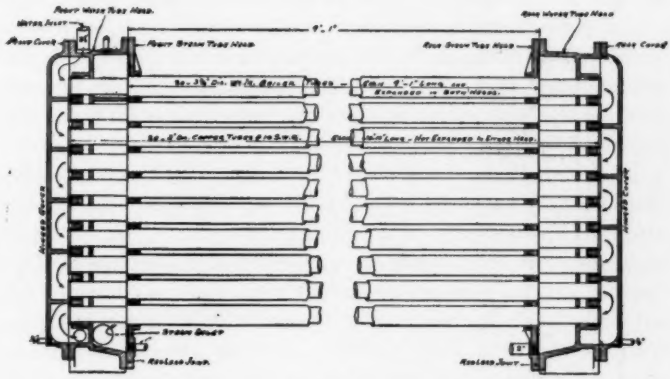


FIG. 3.

As has been said, steam from the boilers is admitted (through a Dinkle reducing valve) to the steam chamber of the first effect, and also some steam from the pressure-reducing tank.

The piping is so arranged that chemical solutions may be circulated through the entire system for cleaning the tubes of the heaters and effects. It was found after the six-day run that there was only a light scale on the tubes of the heaters, varying from $\frac{1}{64}$ in the first to $\frac{3}{64}$ in the third. The tubes of the first and the second effects were practically clean. In the third effect the incrustation was $\frac{5}{16}$ inch thick. By operating the plant in a slightly different way, as was done experimentally prior to this test, Mr. Lillie found no heavier scale in the third than was found in the first and second effects. At the end of the third day of the test the plant was shut down for several hours to permit the removal of this heavy scale from the third effect. In all cases the thickness of scale was greatest on the lower tubes and on the bottoms of the tubes. Mr. Lillie uses the following method of cleaning: A solution of carbonate of soda is run through the heaters and effects (being heated at the same time). This Na_2CO_3 acts on

the insoluble scale (which is mostly sulphate of lime), and soluble sulphate of soda and carbonate of lime are formed, the last being soluble in hydrochloric acid. The $NaSO_4$ passes off in the water. A dilute solution of hydrochloric acid is then run through the heaters and effects. The remaining carbonate of lime reacts with the acid, forming soluble calcic chloride, carbon dioxide and water. All soluble salts formed pass off with the solutions. Only practical tests will demonstrate fully the efficiency and practicability of this method of cleaning.

In this trial only fresh feed (which was a part of the output of the plant) was used in the boilers. The plant was at first fitted to be worked on a sea-water system. The proposed system for this is as follows: The sea water is passed through heaters and its temperature raised to that point at which the sulphates (scale-forming elements) become insoluble. The water then passes to a large settling tank in which the now insoluble sulphates are deposited. From the settling tank the water passes to the boilers. Only enough is to be evaporated in the boilers to furnish steam for the pumps, etc. (say about 25 per cent.), the remaining 75 per cent. goes to the pressure-reducing tank and thence to the effects for evaporation. The boilers were thus to act more as heaters; and even if the scale-forming sulphates were not all deposited in the settling tank, and much remained in suspension (not in solution) it was thought that little or no hard scale would be formed in the boilers owing to the facts that the sulphate of lime was not in solution in the sea water (only in suspension), and to the other fact that 75 per cent. of the feed to the boilers was constantly running away from the same. As the effectiveness of the settling tank had not been demonstrated, and as scale would prove very destructive to the boilers, this method was abandoned. As 35 per cent. of the total output goes for feed to the boilers, the capacity of the plant would be greatly increased if the salt-water system could be successfully used.

The contract required that the plant should prove itself capable of making from sea water 60,000 U. S. gallons, net, of distilled water per 24 hours, for six days of each week. This allows

one day out of each week for cleaning, and it is thought that this will prove ample, even with heavy incrustations in the third effect. With the Yaryan system, as used in the plant at Key West, when running only eight (8) hours each day, five days out of every forty are required for cleaning; running 24 hours each day, 20 per cent. of the time would be required for cleaning. In the Yaryan system the sea water passes through the tubes, and the scale formed is less readily removed.

The results of the six-day test of the "Lillie" plant are given below. From the table it will be seen that, for the total or gross output of the plant, 21.58 pounds of water were distilled per pound of coal; for the net output, after deducting the feed for the boilers, 13.98 pounds of water were distilled per pound of coal.

Duration of test in hours	144.
Number of boilers in use	3.
Mean temperature of the atmosphere	68.29
Mean temperature of sea water	69.58
Mean temperature of water from condenser to heater	89.83
Mean temperature of water leaving heaters	306.7
Mean temperature of discharged brine	140.42
Mean temperature of feed water	120.3
Mean temperature of distilled water	109.3
Mean density of sea water entering first effect	1.$\frac{1}{32}$
Mean density of discharged brine, degrees B	8.58
Mean pressure in boilers, pounds per square inch	115.92
Mean pressure in reduced-pressure tank	11.12
Mean pressure in first effect	10.79
Mean vacuum in first effect	0.
Mean vacuum in second effect	5.42
Mean vacuum in third effect	24.23
Total water distilled, cubic feet	73,318.
Feed water in cubic feet	25,783.
Net output in cubic feet	47,535.
Total water distilled, gallons	548,418.64
Feed water used in boilers, gallons	193,856.84
Gallons per 24 hours	59,260.3
Net output in gallons	355,561.8
Total water distilled, pounds	4,568,327.
Feed water used, pounds	1,606,497.48
Net output of distilled water, pounds	2,961,829.79
Percentage of total water used for feed	35.16

Total coal expended, pounds	211,677.5
Refuse, ashes, pounds	28,275.
Combustible, pounds	183,402.5
Percentage of refuse	13.35
Pounds of water distilled per pound of coal	21.58
Pounds of water distilled net per pound of coal	13.98
Pounds of water distilled per pound of combustible	24.98
Pounds of water net output per pound of combustible	16.14
Pounds of water evaporated in boilers per pound of coal	7.58
Pounds of water evaporated in boilers per pound of combustible	8.65
Ratio of evaporation in the multiple-effect system to the evaporation in the boilers per pound of fuel	2.84
Same ratio for the net output	1.84

The principle upon which multiple-effect evaporators act is not generally understood owing to the type being somewhat uncommon, and, indeed, at first glance, it appears to be something of a phenomenon to obtain 20 pounds of fresh water from the $7\frac{1}{2}$ pounds of steam produced by the combustion of one pound of coal in the boiler. A short explanation, therefore, of the theory is not amiss in completing this report, and it will be of interest to all engineers who have noted the output of such plants, but have deferred the work of tracing the steps of the operation.

The figures given below are approximate only, and merely to show the theroetical possibilities. No account is taken of loss by radiation or discharge of heat with the brine mixtures, while the "total heat" of the brine in the several effects is taken as that of pure water. Also the water is supposed to be fed to each effect at the sensible temperature due to steam at the pressure in each, to simplify explanations. Peabody's tables have been used in the calculations.

The steam chamber and interior of tubes of each effect is here called the *steam side*, and the outside of tubes or salt water and vapor space is called *water side*, for brevity's sake.

The pressure in the water side of first effect 0 pounds = 14.7 pounds absolute.	
Total heat in 1 pound of feed water at 14.7 pounds (absolute)	180.8 units.
Total heat in 1 pound of sea water at 69.58 degrees Fahrenheit	37.7 units.
Total heat to be supplied to 1 pound feed in first effect	143.1 units, (a)

The pressure in the water side of second effect = 5.42 inches vacuum = 12.1 pounds absolute.

Total heat in 1 pound of feed water at 12.1 pounds (absolute).....	171.	units.
Total heat in 1 pound of sea water at 69.58 degrees Fahrenheit...	37.7	units.
Total heat to be supplied to 1 pound feed in second effect.....	133.3	units, . (b)

The pressure in the water side of third effect = 24.23 inches vacuum = 2.8 pounds absolute.

Total heat in 1 pound of feed water at 2.8 pounds (absolute).....	106.7	units.
Total heat in 1 pound of sea water at 69.58 degrees Fahrenheit...	37.7	units.
Total heat to be supplied to 1 pound feed in third effect.....	69.	units, . (c)

Now let us trace the course of 1 pound of steam from the boiler entering the steam side of the first effect.

The heat in this pound of steam is first utilized to evaporate the water in the water side of the first effect until the pound of steam condenses to a pound of water at 10.79 pounds pressure (gage). This pound of water then passes over into the *steam side* of the second effect, and as the amount of heat thus utilized is the difference between the total heat in the pound of steam at the boiler pressure and that in the pound of water to which it is reduced, we have:

Total units of heat in 1 pound steam at 115.92 pounds pressure (gage).....	1,188.
Total units of heat in 1 pound water at 10.79 pounds pressure (gage).....	210.1
Units of heat supplied to feed water in first effect.....	977.9

In order to find out how much water these 977.9 units will vaporize in the water side of this effect, we first ascertain the total heat units necessary to vaporize *one* pound of the feed therein. From the test record we know the vapor pressure in the water side of first effect is 0 (gage), and that the feed comes in from the reducing tank at 11.12 pounds (gage), so that to vaporize a pound of this feed to steam at 0 pressure, we have:

Total heat units in 1 pound vapor at 0 pounds gage.....	1,146.6
Deducting units in the 1 pound feed at 11.12 pounds gage.....	210.8
Heat units necessary to evaporate 1 pound of feed in first effect.....	935.8

Hence with the available heat supplied for this as above we can vaporize here

$$977.9 \div 935.8 = 1.045 \text{ pounds.}$$

Second Effect.—Following the course to the second effect we have delivered to the *steam side* of this, both the 1.045 pounds of vapor (at 0 pressure, gage) from the *water side* of first effect, and the 1 pound of water from the *steam side* of first effect (at 10.79 pounds pressure, gage) and which was condensed from our original 1 pound of boiler steam.

The heat of this *mixture* is now utilized for evaporating feed water in the second effect and is

One pound of water, at 10.79 pounds pressure containing	210.1 units.
And 1.045 pounds vapor containing 1.045 × 1,146.6	1,198.2 units.
Being a total of 2.045 pounds mixture containing	1,408.3 units.

As the pressure in the steam side of this second effect is 0, this heating mixture evaporates feed of the second effect until the mixture becomes water at 0 pounds pressure (gage), when it passes to the steam side of the third effect.

Total heat units in 2.045 pounds water at 0 pounds (gage), or 14.7 absolute, is 2.045 × 180.8 = 369.7.

Subtracting this from the total heat in the mixture, 1,408.3 units, we have 1,038.6 units available for evaporating feed in this second effect.

As in case of first effect, we now ascertain how much feed water in second effect these 1,038.6 units will vaporize.

Total heat units in 1 pound of vapor in water side of this second effect at 12.1 pounds pressure absolute (b)	1,143.7
Heat units in 1 pound feed at same temperature	171.1
Total heat units to be supplied to 1 pound feed in this second effect to vaporize it	972.6

Hence the total pounds of feed water evaporated in this effect by the 2.045 pounds mixture in steam side = 1,038.6 ÷ 972.6 = 1.07 pounds.

Third Effect.—This 1.07 pounds of vapor passes to the steam side of the third effect together with the 2.045 pounds of water from the *steam* side of second effect, and we have in the steam side of the *third* effect the following heat units:

2.045 pounds × 180.8 units (14.7 pounds pressure absolute)	369.7 units.
1.07 pounds × 1,143.7 units (12.1 pounds pressure absolute)	1,221.3 units.
or 3.1 pounds total mixture with	1,591. units.

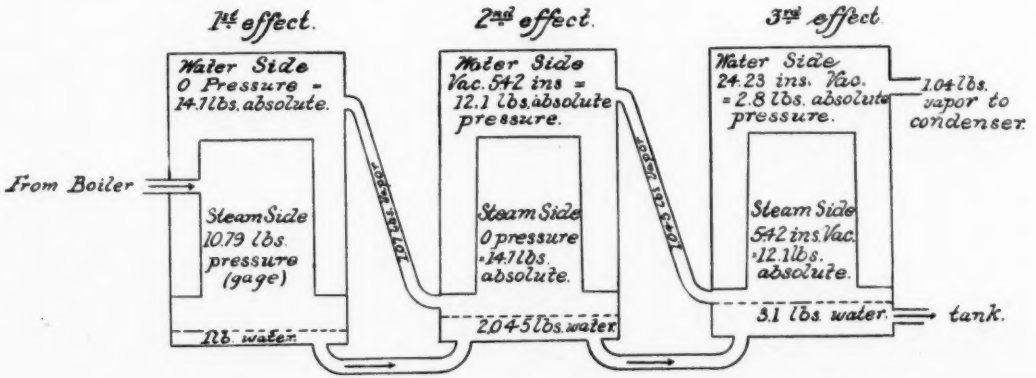


Diagram to illustrate Theory of Multiple Effect Evaporators.

To vaporize one pound of feed water in this effect, we require

Total heat units in 1 pound vapor in water side third effect at pressure of 2.8 pounds absolute (c)	1,124.2
Heat units in 1 pound feed at that pressure	106.7
Total heat to be supplied, units	1,017.5

The heat in the mixture 3.1 pounds in steam side of the third effect is utilized to vaporize the above feed water until the mixture becomes water at 5.42 inches vacuum or 12.1 pounds absolute.

Total heat units in 3.1 pounds mixture at 12.1 pounds absolute	1,591.
Total heat units in 3.1 pounds water at same pressure, 3.1×171.1	532.
Heat units available for evaporating feed	1,059.

Water evaporated in third effect $= \frac{1,059.}{1,017.5} = 1.04$ pounds.

This, when condensed, together with the 3.1 pounds from steam side of this effect goes to the tanks as fresh water, or $3.1 + 1.04 = 4.14$ pounds from 1 pound of boiler steam.

Total heat units in 1 pound steam from boiler	1,188.
Total heat units in 1 pound feed at 120.3 degrees Fahrenheit	88.
Total heat units supplied by boiler to 1 pound water	1,100.
Water evaporated per pound coal	7.58
Total heat units supplied by 1 pound coal ($1,100 \times 7.58$)	8,338.

Heat units supplied to make 4.14 pounds fresh water:

Heat units of 1 pound of steam	1,100.
Heat units of 1.03 pounds of feed, first effect, 1.033×143.1	148.
Heat units of 1.07 pounds of feed, second effect, 1.07×133.3	143.
Heat units of 1.035 pounds of feed, third effect, $1.04 \times 69.$	72.
	1,463.

One pound of fresh water requires, therefore, $\frac{1,463.}{4.14} = 353$ heat units, and

One pound coal would produce $\frac{8,338}{353} = 23.6$ pounds fresh water under the assumed conditions noted on page 96.

FRESHLY HEWN OR GREEN WOOD AS FUEL.

MEMORANDA BY LIEUT. ALBERT MORITZ, U. S. N.

On May 31, 1899, at about 2·30 P. M., the *U. S. S. Newark*, en route to Valparaiso from Montevideo, put into Port Low, Chile, short of coal.

Port Low is a safe harbor on the northern end of Guyatecas Island, one of the Chiloe group, off the coast of Chile. Its shores are well wooded, fresh water is obtainable, and clams, mussels and game birds abound. It is uninhabited, save by occasional parties of fishermen from nearby settlements.

As soon as possible after anchoring a working party of about fifty men, provided with axes, sledges, hammers, mauls, wedges, etc., was sent ashore to fell and split trees into cord wood. When fifty cords had been stacked, about forty additional men were detailed to bring the wood to the ship. They used all the ship's available boats, and were generally towed both ways by the steam launch.

On June 8, in seven and one-half working days—a working day meaning leaving the ship at 7·00 A. M., returning to the ship for dinner at noon, leaving the ship at 1 P. M., and returning at 5, or about eight hours—125 cords were stowed in the ship's bunkers, consuming nearly all the space usually occupied by 795 tons of coal, reckoning 42.5 cubic feet to the ton.

Fifteen furnaces had been prepared in the mean time for wood burning. The grate bars were lowered six inches by lifting the bearing bars out of the usual supports and dropping them into the corrugations of the furnaces. The nine remaining furnaces were left as for coal, and the tubes and back connections thoroughly cleaned. The interiors of the boilers were in excellent condition for steaming.*

* The *Newark* has four double-ended, six-furnace Scotch boilers; length of boiler, 19 feet 4½ inches; diameter of boiler, 13 feet 6 inches; total grate surface, 540 square feet; total heating surface, 16,736.5 square feet.

Fires were lighted at 7·05 A. M., June 8th, in all furnaces, with thoroughly dry wood, old boxes, barrels and oily waste; some green wood, split into small pieces, was used for packing. The temperature of the water in the boilers was 50 degrees Fahrenheit. At 12·00 M. it had risen 15 degrees. All the coaxing of half the engineer's force, splitting the wood finer, the use of oil-saturated waste, dipping the wood in oil, spraying the fires with kerosene, packing thoroughly and lightly, zigzag, and every other way of burning wood known to us, had but little effect. *The wood would not burn.*

As a last resort the bars were removed entirely from one furnace, and the fire started anew in the ash pan. For a time the prospect brightened, and as rapidly as possible the bars of all the furnaces were removed and fires built in the ash pans. With considerable coaxing, and much splitting of the wood, incidently and accidentally breaking a number of floor plates, we managed to form steam in one boiler at 7·00 P. M., five minutes less than twelve hours from the time fires were lighted; we did not get five pounds of steam until midnight, or about seventeen hours after having lighted fires. During the remainder of the night the pressure on all boilers increased about three to five pounds per hour.

The steam thus generated was enough for heating the ship, and occasionally running a feed, a flushing or a bilge pump, the jacking or the work-shop engine, but it was evident that we could not make enough to run one main air pump.

During the 9th of June the fires improved, so that it was believed that two boilers—twelve furnaces—would do for heating purposes after that night. On June 10th a good bed of wood coals encouraged us to let another boiler go, and get along with one—six furnaces.

By this time we found that the only way to get the wood to burn was to split it as fine as possible, and in this work we were assisted by the ship's force, who turned the berth deck into a wood pile during the day.

Each boiler in use consumed wood at the rate of eight or nine cords per day. The difficulty in burning it was due to its

greenness and thorough saturation. The following table gives accurate data on this point:

Specimen.	Weight in lbs. June 8, 1899. Green.	Weight after being thoroughly dried over engine-room battle gratings, 3 feet above L.P. cyl., Aug. 18, 1899.	Per cent. of moisture, based on weight of green wood.
A	74	37	50
B	52	24	55.8
C	59.25	27.25	54
D	23	15	34.8

The Indian or Spanish-Indian names of the specimens were obtained from Indian and Chilian traders who visited the ship from Melinka, a nearby settlement. They called A, a large, smooth-barked, straight-grained tree, white and fibrous, corresponding nearly to North American beech, Mahiu; B and C, species of cinnamon laurel, of very much the same appearance as A, Canelo; D, a very hard, tough, non-fibrous wood, small trees, Luna.

D was undoubtedly the best burning wood, but unfortunately this was not known until all of the 125 cords was on board ship; it represented less than 4 per cent. The balance was about equally divided between A, B and C.

The specific gravity of either of the samples of green wood was greater than that of sea water, as sticks when dropped overboard sank very rapidly. When dry, the wood compared in weight with our hickory, hard maple, white oak, beech, red and black oak; specific gravity about 0.9.

The average weight of one stick of the wood when green was 52 pounds, and it took 125 sticks to make a cord, this being the average of four carefully stacked cords, so that a cord of green wood weighed 6,500 pounds, or, using 52 per cent. as the moisture equivalent, that being the average of the greater part of the wood we had, about 3,120 pounds if dried out thoroughly.

"Kent's Mechanical Engineer's Pocket Book," under the head of "Heating Value of Wood," states it is safe to assume that $2\frac{1}{4}$ pounds of dry wood are equal to 1 pound average quality of

soft coal. On this assumption one cord of this wood, if dry, would have been equivalent to about 1,387 pounds coal.

The same authority says that if wood is not dry, each 10 per cent. of moisture will detract about 12 per cent. from its value as fuel. Hence, $5.2 \times 12 = 62.4$. Deducting 62.4 per cent. from 1,387, we have but 522 pounds, as the coal equivalent of one cord of the green wood. So the whole 125 cords had a coal value of but 65,250 pounds, or about 29 long tons.

The data given is original and accurate, and it is interesting to compare it with data given by authorities on wood in Kent, Haswell and other pocket books.

The following points are given as a practical result of the wood-burning experience at Port Low:

1. Green wood cannot be burned rapidly enough to generate sufficient steam to run a main engine.

2. In using green wood, do not allow more than 500 to 600 pounds as the coal equivalent of one cord.

3. In burning wood, especially green wood, in Scotch boilers, remove grate bars and burn in ash pans.

4. One cord of wood stowed in bunkers occupies the space of about six tons of coal.

5. Fifty sailormen—not professional woodchoppers—can fell, split and stack 125 cords of wood in seven and one-half working days of eight hours each. This is equivalent to about one-third cord per man per day.

6. Twenty-four hours is required to raise steam of fifty pounds pressure from water at 50 degrees Fahrenheit in a six-furnace, double-ended Scotch boiler. Ten cords of green wood is required to form steam, and ten cords additional to raise the pressure.

7. If it is necessary to use steam to any considerable extent, such as running a flushing pump and an auxiliary condenser, it is impossible to maintain fifty pounds pressure. A dynamo engine of about twenty-seven I.H.P.—80 volts, 200 ampères—could not be run at all.

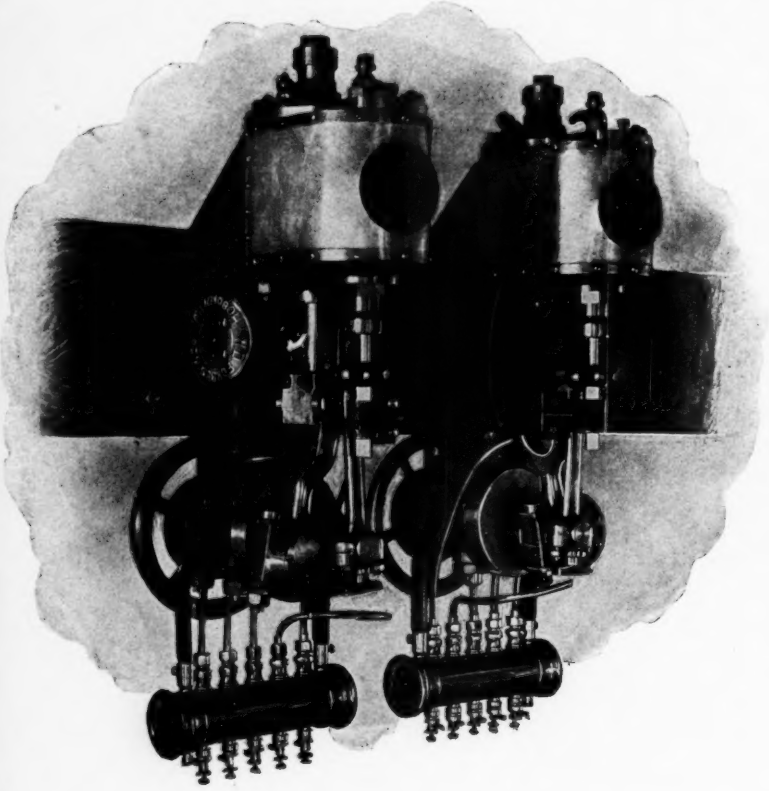
INTERCHANGEABILITY OF UNITS IN MACHINERY.

By W. D. Forbes, Associate Member.

Interchangeability in small and often large mechanical contrivances has resulted in cheapening product and adding to the comfort of all those who have had anything to do with mechanics. There is no place where the simplicity of parts is such an advantage as in weapons of war, and especially at sea. Weight afloat is such an important consideration that every care has to be taken not to incur it in the shape of unnecessary spare parts, but to be without these entirely might prove disastrous.

The value of interchangeability of parts is recognized by naval men, but cannot interchangeability of units be introduced to a very great advantage? That is, why cannot, for example, the circulating-pump engines of a torpedo boat be so made that for a destroyer, exactly the same design in every respect may be used? Perhaps the design would not be exactly right for either destroyer or torpedo boat, as it might not take twice the power for the larger boat, yet, provided the weight is not too much, the fact that artificers and officers going from one boat to another would understand the details of these engines without having to make any investigation or studying of them, would be very advantageous.

Again, in case of actual warfare, a badly disabled destroyer's circulating-pump engine parts could be taken to make good that of a torpedo boat, or the entire pump could be taken from one boat to another. To illustrate the matter of this auxiliary pump, the small engine shown in the cut was built for a torpedo boat, but a destroyer could have a second engine fitted on the inboard side of the shaft, and the total weight of the two single-cylinder engines would be 270 pounds as against 300 pounds weight of the double engine which is to be used in the destroyer, and this



extra 30 pounds would, perhaps, be made up in the additional weight of the bracket on the inboard end of the pump. Again, a double engine has about the same number of working parts as the two single engines, so nothing is lost or gained in that direction. It is, of course, a little more trouble to fill the oiling boxes on two engines than on one, but the same number of oil drips would have to be looked to in either case. The two single engines however have the advantage of being entirely independent of each other, and if one gave out or was damaged it could be disconnected and its mate left to "hobble home" with, or out of the way of the enemy, while with a double engine if a part gives out it is a case of the entire loss of power until repairs are made.

There is, to-day, among pumps makers, a good system of interchangeability in the wearing parts of each individual pump, but the interchangeability of the entire unit of one maker for another is not regarded. There is no reason why the position of the holding-down bolt holes should not be as carefully jiged as the valve-chest cover holes, not only in relation to each other, but in relation to the position of these holding-down bolt holes with the induction and exhaust. This would make the entire pump unit readily replaceable, one with another, to the great advantage of the people afloat. It is assumed, the idea of making something different from somebody else so as to insure repairs coming home is an exploded commercial system.

The idea of interchangeability of units can also be very easily carried out on small engines, such as are used in the launches of the Navy. It simply means that the largest engine which the department is willing to use for a given output of power must be taken, so to say, as a standard, and all the smaller engines, which, by reason of higher rotative speed, variations in proportion, etc., etc., give equal power, must be made to conform to this largest size, as regards the position of the holding-down bolt holes in the bedplate, the position of center of shaft coupling and position of its face, and also the exact positions of the steam and exhaust openings. The rest of the engine design can be left to the vagaries of designers.

In case a launch engine needs repairs, the engine can be readily lifted out of the hull and replaced by one of another make, provided the above conditions are adhered to, and of course an engine can be overhauled in the shops or on board a repair ship much more economically and expeditiously than in the hull of the launch.

At first sight this idea does not seem very practical, but a little measuring and thought will show it is. The Navy could accomplish this end by establishing a standard for the positions of the various parts above named, and launch-engine builders could and would conform to the demands laid down.

In regard to boilers, the same idea can be carried out as with the engine; certain positions must be established for feed water inlets, blow-offs, steam connections, etc., leaving the detail of the design of the boiler to the general fantastic "cussedness" of boiler designers throughout the world.

Referring again to the question of small engines of the auxiliary class, it certainly is preferable, for instance, to have torpedo-boat blower engines exactly the same as those of destroyer blower engines, running those on the latter boats at higher revolutions to obtain a larger supply of air, while these revolutions could be cut down to meet the demands of the similar boats. It is, of course, true that a small saving of weight might be effected by making separate designs, but that would not amount to very much; there would be the minimum weight in the destroyers which require the greater speed, and at most there will be but a slight additional weight to be cared for in the torpedo boat.

Referring to what is now being furnished to the government in the line of auxiliary engines, inspectors sometimes request modifications in the details of engine designs which come under their particular inspection, when an engine exactly similar in general design may be building at some other works than those with whom the inspector is detailed. This, of course knocks the interchangeability of parts most effectively on the head, demanding extra attention on the part of the officer in charge, and on account of the engines being in general appearance exactly alike,

the change in detail is likely to cause serious trouble even when the officers in charge are using the utmost care.

To illustrate this point, the piston rods of a small auxiliary engine were modified by an inspector so that in one case the piston rod could be readily drawn through the stuffing box while in the other a shoulder on the upper end of the rod demanded a specially designed stuffing box. The drawing on board would show this difference in design, but it is so small that it is likely to escape notice.

In short, it is fair to say that the interchangeable-unit idea presents no insurmountable barriers, it simply needs skill in making a compromise, which is always demanded in engineering. It will result in some slight additional weight at times, a considerable larger margin of power than is needed at others, but, in small auxiliary machinery particularly, the practical advantages far outweigh the objections.

The matter is more seriously worthy of study by the designers of our own naval machinery by reason of the fact that every indication points to the early addition of a great number of new vessels, both large and small, to our fleet, and there appears to be no good reason why provision for interchangeability should not be at least begun now.

The advantages of the system are left to the consideration of those who know what it is to be ten miles from a lemon and to want lemonade.

THE PROPERTIES AND POSSIBLE USES OF NICKEL-STEEL.

[From "Engineering News."]

The world's production of nickel in 1897 amounted to 5,429 tons, the bulk of which came from the Canadian mines and from those of New Caledonia. In 1890 a conservative estimate places the total production of nickel at about 7,000 tons. During the interval between these two dates no new mines of any importance were discovered, the increase recorded being due wholly to the greater output of the well-known nickel-producing districts named. These facts are worth noting carefully, as they establish the physical limit of nickel-steel production until some new discovery or development, of which we now have no indication, lays open a greater wealth of nickel ore for our use. Employed in the usual proportion of 3 per cent. to 3½ per cent. as an alloy of steel, the nickel output of 1899 would make about 230,000 tons of nickel-steel. As already stated, these figures establish the physical limit of nickel-steel production at the present time. For obvious reasons the commercial limit is much below these figures. Under no circumstances, therefore, which we have any reason to anticipate can nickel-steel constitute more than a small percentage of the total steel consumption of the world. This is a fact which it is important to keep in mind in any speculation upon the future development and possible uses of nickel-steel in engineering works.

The fact that we so soon reach a limit in the possible production of nickel-steel cannot be anything but a matter of regret to engineers. Of all the various alloys of steel which have come into prominence in recent years, that of nickel and steel admittedly presents the greatest promise of general utility for engineering purposes. Considering the truly remarkable properties of the metal, however, the quantity consumed for other

purposes than armor plate is, it must likewise be admitted, surprisingly small. One reason for this is, of course, that while the purposes for which it has been chiefly employed are important, they do not call for large quantities of material. A second reason is undoubtedly to be found in the higher price of the alloy as compared with simple steel. Giving these facts all the prominence which is their due, however, it must be ackowledged, we think, that the failure to take full advantage of the opportunities which nickel-steel offers as a structural material is due to the fact that engineers are to a considerable extent unacquainted with the true properties and limitations of the material. This lack of familiarity is doubtless unwarranted by the lack of reliable information, but there is no doubt but that it generally prevails, and, moreover, that it is in many instances responsible for the hesitation with which engineers are adapting nickel-steel to many uses for which it is particularly well adapted.

We have been prompted to make these remarks by reading the excellent paper on nickel-steel, which was presented at the San Francisco meeting of the Institute of Mining Engineers by Mr. David H. Browne, in September of last year. This paper is by all odds the best general summary of the present experience and opinion respecting the properties and uses of nickel-steel which has appeared for some time. In view of the conditions just mentioned, moreover, much of the information which it contains respecting the properties of this useful alloy, and particularly the speculations which it suggests respecting its more general adoption in engineering work, are of exceptional interest.

At the very outset Mr. Browne points out that the physical tests of metallic nickel furnish no explanation of its remarkable effects when alloyed with iron. The most notable of these effects is the manner in which it increases the elastic strength of the steel to which it has been added. This fact is not exhibited so much by the increase in the elastic limit of the steel as it is by the greatly-increased resistance which it develops against numerous and repeated strains. Expressed in another way, the addition of the small percentage of nickel extends the limit at which molecular fatigue begins, as distinguished from molecular distor-

tion, which is the elastic limit of the metal. The testing-room parlance of America has no well-known designation for the former phenomenon, but among European engineers it is commonly known as the "limit of proportionality." The limit of proportionality is always considerably inside the elastic limit, and it is in increasing this that the greatest influence of the nickel alloy is exhibited.

A few figures of the results of tests will demonstrate the nature of the quality just mentioned more clearly. According to tests made by Professor Rudeloff, of Berlin, an alloy of 8 per cent. of nickel with pure iron has 3.8 times the elastic strength of the pure iron. With higher percentages of nickel the limit of proportionality decreases. In tests made by numerous and rapidly alternating flexures at the Pope Tube Works at Hartford, Conn., it has been found that taking 0.1 per cent. carbon steel loaded to about 60 per cent. of its elastic strength as a basis, and assuming that it will withstand 100,000 flexures, then a 0.25 per cent. carbon steel will withstand about 200,000; a 0.5 per cent. carbon steel about 400.000, and a 0.25 carbon and 5 per cent. nickel-steel will withstand about 1,000,000 flexures. The enormously greater ability of nickel-steel to resist fatigue as shown by these last figures is the property which most emphatically distinguishes it from simple steel.

Turning now to the influence of the nickel alloy upon the elastic limit and ultimate strength of steel, we find it somewhat more difficult to draw accurate comparisons. The percentage of carbon present and the character of both the mechanical and heat treatment have so great an influence upon these properties in steel that it is unusually difficult to obtain identical conditions, except, of course, in the percentage of nickel. Furthermore, the effect of the nickel varies with the percentage of carbon present in the steel. Its addition always increases both the elastic limit and the ultimate strength, but the proportion of increase is greater with steels high in carbon than with those low in this element. A few figures selected from different sources by Mr. Browne, and rearranged here in more convenient form for comparison, will serve better than general statements to show

the effect of a nickel alloy upon the elastic limit and ultimate strength of steel. These figures are in all cases the results of actual tests of the material. It will be noted particularly that those furnished by the Bethlehem Iron Company, show that in a 0.2 per cent. carbon steel the gain in the elastic limit due to 1 per cent. of the nickel is 5,714 pounds, while in a 0.5 per cent. carbon steel it is 10,570 pounds. Tests made by other experimenters give other values, but they all bear out the general truth of the statement made above:

TABLE SHOWING INCREASE IN POUNDS PER SQUARE INCH DUE TO ADDITION OF 1 PER CENT. NICKEL TO STEEL.

Tests Made by—	Per cent. Carbon.	Elastic Limit.	Ultimate Strength.
Canadian Copper Co.	0.1	4,384	3,814
Pope Tube Works	0.25	4,000	5,000
Mr. Allen, Glasgow	0.14	5,485	3,509
Bethlehem Iron Co.	0.2	5,714	8,571
Bethlehem Iron Co.	0.5	10.570	8,571
Crescent Steel Co.	1.1	18,597	20,484

The particularly remarkable feature of this increase in ultimate strength and elastic limit due to the addition of nickel is that it does not materially reduce the ductility of the steel. When compared with simple steels of the same percentage of carbon, nickel-steel shows a slight decrease in elongation and contraction of area, but when compared with simple steels of the same strength and elastic limit it shows an increase in both of these properties. Mr. Browne considers that, as a rule, a 3 per cent. nickel-steel will have from 20 per cent. to 30 per cent. greater elongation than a simple steel of the same tensile strength, while, as compared with a simple steel of the same carbon percentage, the nickel-steel will have about 40 per cent. greater tensile strength and practically the same elongation and reduction of area. Besides adding to its ductility the use of nickel alloy with steel materially increases its ratio of elastic limit to ultimate strength.

When tested by impact for flexure, nickel-steel shows greater stiffness and greater toughness than simple steel, the ratio of in-

crease with 3 per cent. nickel-steel being, respectively, about 48 per cent. and 45 per cent. Its resistance to compression increases directly with the percentage of nickel up to 16 per cent., when, according to tests made by Mr. R. A. Hadfield and quoted by Mr. Browne, the samples showed a shortening of only 1 per cent. under 100 tons pressure as compared with a shortening of 50 per cent. exhibited by simple steel. Like its compressive strength, the shearing strength of nickel-steel increases directly with the proportion of nickel up to 16 per cent., when it is about one-third greater than that of simple steel. The loss of strength by punching nickel-steel is not greater apparently than that of mild boiler steel. Steel which contains over 3 per cent. of nickel is very difficult to weld. The mechanical working, that is, rolling, hammering, etc., of nickel-steel materially increases its strength and ductility. One of the most notable properties of nickel-steel, however, is its great increase in elastic limit and ultimate strength due to quenching. Its great sensitiveness to heat treatment places the proper annealing temperature for nickel-steel considerably below that required for simple steel. In proportion to its elastic and tensile strength, nickel-steel is softer than ordinary carbon steel, and its density is about the same for small percentages of alloy. Nickel-steel suffers less from corrosion than ordinary steel, the difference being very slight for the regular 3 per cent. to 3½ per cent. nickel-steels, and increasing up to 18 per cent. nickel-steel, which is practically non-corrodible. All nickel-steels have a high electrical resistance, the resistance of from 25 per cent. to 30 per cent. nickel-steel being about 48 times that of copper. The coefficient of expansion varies between wide limits, depending upon the percentage of the alloy.

This preceding enumeration of the chief properties of nickel-steel, which is necessarily very much condensed as compared with their statement in the paper, bears out fully, it seems to us, Mr. Browne's assertion that it is a metal of remarkable characteristics. Of the various properties mentioned, it is evident that the increased capacity to do work due to its resistance to molecular fatigue is of the most importance to the mechanical

engineer. Stated plainly, the engineer has in the ordinary 0.2 per cent. to 0.4 per cent. carbon and 3 per cent. to 5 per cent. nickel-steel, a metal with all the ductility of a low-carbon steel, and at the same time the strength and stiffness of a high-carbon steel. These qualities suggest at once the utility of nickel-steel for purposes where a decrease in the weight and dimensions of the component members is desirable in connection with the ability to endure heavy and continuous work. Shafting, piston rods, crank pins and the like are good examples for such members, and it is for them that nickel-steel is principally employed, excepting always armor plate, of course. At this point a few words may well be said toward setting aright the quite common impression that the extra cost of nickel-steel of necessity precludes its use for other purposes than high-priced special forgings of the character mentioned.

Allowing a price of 35 cents per pound for nickel, the usual addition of 3 per cent. of that metal to steel increases the cost of the raw material about one cent per pound, or $20 per ton, according to Mr. Brown's calculations. After the nickel-steel is once in ingot form, it costs no more to work it than it does ordinary carbon steel. The question then is, does this increase of cost of $20 per ton count nickel-steel out of consideration for the more ordinary structural purposes where rolled plates and shapes are employed? Let us see, for example, how this question will be answered in bridge work, which is one of the most important engineering uses of steel. In bridge material high elastic strength is held paramount to greater tensile strength accompanied by a lower elastic limit. Opposed to this there is the equal necessity that the material shall have a high degree of ductility or toughness to withstand the impact shock of rolling loads. In the combination of these two qualities nickel-steel possesses, as has already been pointed out, a marked superiority over carbon steel. If the two metals were equally available at the same price, there would not, we think, be much doubt that the bridge engineer would always select the nickel-steel for his work. With the difference in cost which actually exists the problem is more difficult to settle. It resolves itself into the

question whether the superiority in the working strength of the nickel-steel will allow members made of it to be constructed with enough smaller section to make up in reduced weight for more than the extra cost of the nickel-steel. If this cannot be accomplished there is obviously little use in considering the general substitution of nickel-steel for bridge work, and this is evidently a question which will need more data to settle conclusively than we have at present.

There is, however, still another feature of this subject. If it should be settled that the use of nickel-steel throughout is undesirable, is it not quite possible that it may be substituted with advantage in place of the commonly used hard and medium carbon steels for certain members. The severe duties of bridge eye bars, for example, have led, in some recent instances, to the use of simple steel having as high as 0.4 per cent. of carbon in order to get the necessary high elastic limit. In this manner the engineer gained his immediate object, but he did it at a loss in the ductility of his members and at the danger of deterioration in manufacture. The thing which it is chiefly important to point out, however, is that the same high elastic limit can be obtained by using nickel-steel and still retain all the ductility of a steel low in carbon. These few remarks are necessarily incomplete, but they indicate, we think, that the possible use of nickel-steel for bridge and structural steel work is by no means one which can be ruled out of consideration by engineers, without careful investigation.

Turning now to the other remaining extensive use of nickel-steel in plates for boiler and tank work, and for ship's hulls, Mr. Browne points out that in some respects this material presents even greater claims for consideration than it does in bridge and general structural work. No less an authority than Sir William Henry White, Director of Naval Construction of the British Navy, has said that, by using nickel-steel in an Atlantic liner of 20 knots speed, about 1,000 tons in weight could be saved, which could be used in increased capacity for freight or which would suffice to raise the speed one knot without altering dimensions. In warships this reduction of the dead load would be of even

greater importance by adding to the coal capacity and the weight available for armor and armament. The fact that the loss by corrosion of nickel-steel exposed to salt water is much less than that of carbon steel, constitutes another element of especial fitness for hull plates. The experience with nickel-steel for boiler plates is limited, but its suitability for this purpose seems evident. Its greater elastic and tensile strength, and far greater ductility in proportion to its strength, suggests its special fitness to meet the increasing pressures, greater strength and more severe duties which are now being required of steam boilers, especially for use on shipboard.

So far we have been chiefly engaged in pointing out some of the possible fields of utility for nickel-steel. To catalogue the uses to which the new alloy has already been put with greater or less success would take more space than can conveniently be given in these columns, but a brief review of a few of them is desirable.

As a material for armor plates the nickel-steel alloy has proved its advantages beyond question, and nickel-steel armor plate is now employed by all the naval powers. It has gained an almost equally permanent standing for the construction of shafting and engine forgings for warships and for the more costly vessels of the mercantile marine. The principal reason for this popularity of nickel-steel in marine engine forgings is, of course, the great reduction in weight which it affords as compared with simple steel of the same strength. For example, the hollow nickel-steel propeller shaft of the *U. S. S. Brooklyn* has a diameter of $17\frac{1}{8}$ inches, and weighs 19,112 pounds. According to calculations made by Mr. H. F. J. Porter, M. Am. Soc. M. E., a solid simple steel shaft of the same strength would be 18.9 inches in diameter, and would weigh 53 per cent. more. Another advantage of nickel-steel for marine engine construction is its greater safety, owing to the warning which it always gives of failure.

The same characteristics which make nickel-steel shafting and forgings superior to ordinary carbon steel in the engine room of a warship suggest their utility for other purposes where the

requirements are similar, and it is natural to find that this material is winning its way in the field of railway mechanical engineering. In some respects this is a more promising field of usefulness than that of naval construction. It is, however, one which is controlled by more conservatism and particularly by a greater need of making every item of extra expenditure pay for itself in increased durability and efficiency. For such purposes as locomotive piston rods, crank pins, etc., nickel-steel has already gained a firm footing in the mechanical departments of American railways. In England tests made on nickel-steel driving-wheel tires have shown that they possess a material superiority over the low-carbon steel tires commonly employed in that country. The usual English specifications require that railway tires shall stand compression one-sixth of their diameter without cracking. Actual tests made on 39½-inch tires of 0.18 carbon and 3 per cent. nickel-steel are given by Mr. Browne, which show that the tire was compressed to 19 inches, or more than three times what the specifications required, without showing signs of fracture. Tests of the steel axles, of which 600 were supplied for the 100,000-lb. ore cars of the Pittsburg, Bessemer & Lake Erie R. R., showed that axles of 0.25 per cent. carbon and 3 per cent. to 3½ per cent. nickel-steel were as stiff under impact as ordinary steel of 0.4 per cent. to 0.45 per cent. carbon, and would withstand 50 per cent. more blows. In every case the nickel steel axles gave warning of failure, while the common steel broke short without warning.

Among the miscellaneous or special uses to which Mr. Browne mentions nickel-steel alloys as being applied are resistance wire, bicycle tubing and spokes, staybolts, fire-box sheets, boiler tubing, firearms, safes and vaults, bobbin spindles, and a great variety of other purposes for which some peculiarity either of strength, ductility or incorrodibility gives it special fitness. One of the most promising of these uses for nickel-steel is the making of tool steel of it. Extensive experiments in this direction have been made by the Damascus Steel Company, of Pittsburg, Pa., and they are of so interesting a character that we quote the

results given by Mr. H. J. Williams, of that company, to Mr. Browne, as follows:

"Sound billets of nickel-steel of any desired percentage in nickel or carbon can now be obtained. The working of these billets into tools or wire rods presents no especial difficulties. The nickel-steel works tougher than simple steel; causes more rebound of the hammer and necessitates a lighter draft on the rolls or dies.

"For tools, the alloy containing about 0.80 per cent. carbon with 3 per cent. of nickel, is probably the best alloy for every-day use. Increasing the nickel to 5 or 6 per cent. increases the strength, but necessitates skilled treatment in forging. Tool-steel with 0.80 per cent. carbon, and from 3 to 5 per cent. nickel, possesses all the hardness of high-carbon simple steel, without its brittleness. Nickel-steel shows very pronounced toughness. If nicked when hot, and then struck on the anvil after it has cooled, it is very liable to break under the hammer—not at, but beyond the nick; while carbon steel almost invariably breaks at the point where it was nicked when hot. This nickel tool steel has a satin grain and does not crack on quenching as readily as simple steel; the tensile strength runs as high as 260,000 pounds per square inch. A nickel-steel tool containing 4 or 5 per cent. of nickel, with 0.80 per cent. carbon, is as hard after tempering as the best simple tool steel of 1.00 to 1.25 per cent. carbon, without the brittleness and glassy nature which distinguish the latter. When used for drills, the nickel-steel appears to work with much less than the usual friction, and does not become so hot in use as carbon steel.

"Up to 6 per cent. of nickel, the hardness obtained by quenching is as largely dependent on the amount of carbon present as in simple steels, the only difference being that nickel-steels appear to attain a desired temper with 0.20 to 0.30 per cent. less carbon than simple steels. Nickel-steels are consequently exceedingly sensitive to heat treatment, but on the other hand, are less easily spoiled by overheating, and therefore may be worked at somewhat higher heat than a carbon steel that will give the same temper."

While the list of uses for nickel-steel which have been mentioned is necessarily far from being exhaustive, it shows clearly, we think, that there is a very wide field for its employment by the engineer. The fact that only about 10,000 tons of nickel-steel were produced in the United States in 1899 for other purposes than armor plate also indicates, we think, that engineers have only just begun to wake up to the fact that they possess in this new alloy a remarkable metal for high-grade machine and structural work. This a condition which we may expect to see remedied, but there is another difficulty in the way of the more universal use of nickel-steel which would be otherwise possible, which is the limited amount of available nickel.

At the present time there are only two regions in the world which produce nickel in any quantities, and their output is not large and does not show any signs of being capable of a notable increase. It is not well known, even, so far as we have been able to discover, just what the extent of these mines is, and whether they are capable of indefinite expansion or are likely to be soon worked out. One thing we do know, and that is that the increased demands for nickel in 1899 raised the price about five cents per pound, with the prospect in view of further advances during the present year. It needs no great argument to demonstrate that this will cut short the demand for steel making, which might otherwise be expected during 1900.

All things considered, then, it seems that the greatest bar to the increased employment of nickel-steel by engineers beyond a few important purposes where great quantities are not required and where cost does not count, is the questionable ability of our present mines to produce the requisite supply of nickel at reasonable prices.

POWER LOSSES IN THE MACHINE SHOP.

By Charles H. Benjamin.

[Reprinted from "Cassier's Magazine."]

The object of a machine shop, with its array of glittering machines, its maze of belts and long lines of shafting, is to remove a certain amount of metal from the rough casting. The shop which will do this with the least expenditure of time, labor and coal is the best shop, and will net its owner the largest returns. It may be well to note that the two elements of time and human labor are by far the most important. A good machine must do its work accurately and rapidly, and must require the minimum of attendance, since the interest account and the pay-roll far outweigh the expense of power.

Admitting this, the fact still remains that a saving of power is not to be despised, and will help to tip the balance in the right direction. One who has not given the subject special attention would, doubtless, be astonished to learn how small a fraction of the power generated in the engine room finds its way to the points of the cutting tools. Stating the case roughly, for the ordinary machine shop, every one hundred indicated horsepower of the engine may be thus distributed:—

	Horsepower.
Friction of engine	10
Line of shafting	15
Belts and pulleys	15
Empty machines	15
Cutting metal	45
Total	100

Even this efficiency would probably be realized only when all the machines were working at their full capacity.

The power required to remove the surface of metal depends on the nature of the material and the shape of the cutting tool.

Cast iron consumes the least power of any of the metals in common use and the harder grades of steel the most power. To remove a pound of cast iron per hour on an engine lathe will take from 0.015 to 0.030 H.P., according to the nature of the tool, with a safe average of 0.025, or $\frac{1}{40}$ of a horsepower.

To remove a pound of machinery steel per hour on the same machine will take about 0.04, or $\frac{1}{25}$ of a horsepower. Average engine lathes of from 14 to 20 inches swing will remove from 10 to 20 pounds of cast iron per hour when cutting at full capacity, and consume from $\frac{1}{4}$ to $\frac{1}{2}$ H.P. in the useful work. In turning machinery steel the same machines will remove from 5 to 10 pounds of metal per hour, at an expenditure of from $\frac{1}{5}$ to $\frac{2}{5}$ H.P.

The power expended in running the machine alone will depend very much on its condition. The writer has seen the horsepower consumption of an engine lathe increase from 0.36 to 2.3 H.P. in a few minutes on account of the main spindle becoming dry. The power required to run the average lathe before mentioned, when empty and in fair working condition, will be from 0.04 to 0.16 H.P., exclusive of countershafts, the lower values being for slow speed and the higher for fast speed. A tightening of the work between the centers may easily raise this to 0.30 or 0.40 H.P. If $\frac{1}{10}$ of a horsepower be assumed as an average value of the machine friction, and added to the cutting power, the total power consumed by an ordinary lathe will vary from $\frac{3}{10}$ to $\frac{6}{10}$ H.P., exclusive of counters and belts.

Experiments made at a prominent American locomotive works on large lathes used for turning driving wheels, and driven by electric motors, showed the average power consumed by an 84-inch wheel lathe to be 1.75 H.P., and the average total power used when cutting 5.8 H.P. In considering this extraordinarily large result, it is enough to say that the tools in this shop are worked to their full capacity and remove more metal per hour than is generally believed possible. A number of tests on different lathes, conducted by Prof. J. J. Flather, have shown an average total horsepower of 0.57, the lathes ranging in size from 12 to 80 inches swing. A series of experiments made by the writer on nine different engine lathes, ranging in size from 12 to

22 inches swing, gave an average total cutting power of 0.21 H.P., the machines in this case running under ordinary conditions and not loaded to their full capacity.

It may, then, be safely assumed that an allowance of $\frac{1}{4}$ H.P. for the average load, or $\frac{1}{2}$ H.P. for the maximum load, on each engine lathe in an ordinary machine shop will be sufficient.

A number of different experiments with an iron planer, 24 inches by 24 inches by 6 feet, have shown a consumption of 0.035 H.P. for every pound of cast iron removed per hour and a consumption of 0.065 H.P. for every pound of machinery steel removed per hour. It is more difficult to set a planer tool correctly, and it is more liable to become dulled, than the lathe tool. A planer of the above size may remove 20 pounds of soft steel or 30 pounds of cast iron in an hour, consuming, in cutting metal, 1.3 H.P. on steel and 1.05 H.P. on cast iron. These, however, are large values, and in ordinary work this machine would not consume over $\frac{1}{2}$ H.P.

The power required to drive the empty planer is variable, being greatest on the return stroke on account of the faster speed and rising to a maximum at the instant of reversal. This has been clearly demonstrated by means of diagrams taken with a recording dynamometer from the planer above referred to when empty and when cutting cast iron at the rate of about 25 pounds per hour.

It may be seen that the time of return is just one-half that of the forward motion. The power used in cutting is greatest at the beginning of each stroke, but this may be due to a difference in the depth of cut or hardness of the metal. The jumps in pressure due to reversal are about the same, but those at the end of the return are much greater than those at the end of the forward motion. The average power consumed is about 0.50 H.P. for the empty machine and 1.00 H.P. for the total when cutting. The maximum power at the instant of reversal is 2.8 H.P., but much of this will naturally be supplied by the stored energy of the line shafting. With a heavy planing machine taking a light cut, more power will be used in running back than when cutting.

Six experiments with the planer before mentioned show an average horsepower for the empty machine of 0.25 when running forward, and 0.55 when running backward, with a general average of 0.35 for the whole time. This would give a total consumption of power when cutting metal of 0.50 to 1.65 H.P., with a probable average of about 1 horsepower on ordinary work.

From the experiments at the locomotive works before referred to, the following results were obtained in the case of large planing machines:

TABLE I.

Size.	Horsepower.				Average.
	Motor and shaft.	Empty machine.	Total cutting.		
			Minimum.	Maximum.	
62 inches by 35 feet...	4.4	11.4	20.6	21.6	21.1
62 inches by 35 feet...	.....	5.8	23.0	26.0	24.5
36 inches by 12 feet...	2.7	3.0	11.3	13.8	12.5
24 inches by 13 feet...	1.95	4.3	.....	.....	8.0
36 inches by 18 feet...	3.2	4.3	.....	.....	16.7
56 inches by 35 feet...	4.6	9.9	13.0	13.7	13.3
56 inches by 24 feet...	4.56	6.0	16.0	17.7	16.8

In all the above planers two tools were used and the machines were worked to their full capacity.

Shaping machines will ordinarily remove more metal per horsepower per hour than the larger planers. This is probably due to the fact that in the former case the light tool carriage consumes less power than the heavy platen of the planer with its load. The average amount of power required to run a 16-inch shaper is about 0.15 H.P. when empty, and about 0.65 H.P. when removing 10 pounds of cast iron per hour. Five different shaping machines, varying from 4 inches to 29 inches stroke, showed by test to require an average of 0.48 H.P.

Drill presses such as are ordinarily used in shops require but a small amount of power, and most of this is consumed in driving the machines alone; $\frac{1}{4}$ H.P. would be a fair allowance for an

upright drill of 24 inches swing when drilling holes not over one inch in diameter. In drilling steel at the full capacity of the drill, this has been known to increase to $\frac{3}{4}$ H.P.

Milling machines of the universal type, with centers swinging 10 inches in diameter, when running empty consume an inappreciable amount of power, usually less than $\frac{1}{20}$ H.P. The amount of metal cut per hour by such a machine is ordinarily much less than with lathes or planers, and the power required per pound is much greater. Professor Flather gives the horsepower consumed by the milling machine per pound of metal per hour as 0.14 for cast iron, 0.10 for bronze, and 0.30 for tool steel, or about four times as much as would be used by a planing or shaping machine under the same circumstances. The total power used by the milling machine mentioned above would vary from $\frac{1}{20}$ to $\frac{1}{2}$ H.P. In estimating the power that will be required to drive the tools in an ordinary machine shop doing medium and light work, the preceding figures show that an allowance of from $\frac{1}{4}$ to $\frac{1}{2}$ H.P. for each engine lathe and shaper, 1.0 H.P. for each planer and $\frac{1}{4}$ H.P. for each drill press and column milling machine would be ample. The machines would never be run all at one time at full capacity.

A comparatively small amount of power is consumed by an ordinary counter shaft, when in good condition, but the combined losses due to the loose pulleys, the clutches and the pull of belts on counters and line shafting are considerable. The line shaft in a shop under the writer's care is $1\frac{15}{16}$ inches in diameter and 90 feet long, and is supported by twelve drop hangers, with ball-and-socket joints. This shaft drives nine engine lathes, a planing machine, two shapers, two drill presses, a milling machine, and several smaller tools.

To carry these various machines, thirty belts, having an average width of $2\frac{1}{2}$ inches, run from the line shaft to the counters of the machines. The extreme right of the diagram shows the power required to run the whole overhead system of shafting, belting, clutches and loose pulleys, without special oiling, the horsepower developed being 1.39. The belts were then removed from the pulleys and hung up so as not to touch

the shaft, when the second line was traced, giving a horsepower of 0.46.

This leaves a difference of 0.93 H.P. for the friction of the counters and belts when the machines are not running, or twice the friction of the line shaft. The inclined line shows the effect of flooding the bearings of the line shaft with a thin machine oil, the power falling to less than 0.10 H.P. Replacing the belts on the pulleys gave the last line with a horsepower of 1.02. The difference between this last and the friction of the shafting is still 0.93 H.P., as at first, and shows the power wasted in belt transmission.

A test made on this same line several days later, with the machinery at work, about eight machines being in operation with ordinary loads, showed a horsepower of 2.51. Subtracting 1.39 for the horsepower of shafting and belts, leaves 1.12 H.P. for the power consumed by the eight machines, or about 0.14 H.P. per machine. The percentage of power consumed by shafting and belts is thus 55 per cent., leaving 45 per cent. for the machines themselves. A subsequent test when fifteen machines were in operation, with comparatively heavy cuts, gave results as shown in Table II.

TABLE II.

Kind of machine.	Material.	Size of stock.	Depth of cut.	Horsepower.
Milling.....	Wrought iron.	1.25 in. square.	0 08 inch.	0.092
Lathe.....	Machinery steel.	0.7 in. diam.	0.07 "	0.183
Lathe.....	Machinery steel.	0.86 "	0.05 "	0.183
Lathe.....	Cast iron.	7.48 "	0.04 "	0.183
Lathe.....	Machinery steel.	1.0 "	0.10 "	0.183
Lathe.....	Machinery steel.	0.56 "	0.11 "	0.274
Lathe.....	Cast iron.	11.75 "	0.03 "	0.137
Lathe.....	Machinery steel.	1.02 "	0.04 "	0.320
Lathe.....	Machinery steel.	1.58 "	0.15 "	0.323
Lathe.....	Cast iron.	17.13 "	0.12 "	0.137
Planer.....	Cast iron.	48. in. stroke.	0.15 "	0.960
Shaper.....	Machinery steel.	13.5 "	0.06 "	0.274
Shaper.....	Cast iron.	12.5 "	0.06 "	0.274
Drill.....	Machinery steel.	1. in. drill.	.....	0.274
Drill.....	Machinery steel.	$\frac{1}{8}$ "	.....	0.046

The total power used by these fifteen machines was 3.84 H.P., or 0.255 H.P. per machine. The total power used by shafting

and belts was 1.28 H.P. This experiment gives just 75 per cent. of power consumed by the machines and 25 per cent. by the overhead losses, and probably represents the best that can be expected. Assuming that the power consumed in cutting the metal is three-fourths of the power used by the machine, the work will be distributed about as follows:*

Shafting losses, per cent	12.5
Counters and belts, per cent	12.5
Machines, per cent	18
Useful work, per cent	57

During the winter of 1898–99 several tests were made under the direction of the writer on the power consumed by the shafting, belts and machines in several different rooms of a large manufacturing establishment. The results may be summarized as follows:

Room No. 1.—This room was used as a repair and tool room, and contained the following equipment:

Shafting $1\frac{5}{16}$ inches in diameter and 100 feet long, running at 175 revolutions per minute.

Eleven journals on main shaft, 12 feet apart.

Forty-one belts of an average width of 3 inches.

Four medium drill presses. Five medium shapers.

Six engine lathes, 12 inches to 22 inches swing. One wood lathe, 12 inches swing.

Two surface grinders.

One 18-inch planer. Three medium milling machines.

Emery wheel and grindstone.

The test began at 10.45 A. M., and continued until 5 P. M. Only a few machines were running at a time—from two to five lathes, one of the milling machines, a drill press and one of the grinders. The average power consumed by the shafting and belts was 3.36 H.P. and by the machines 1.65 H.P., a total of 5.01 H.P. This room used, therefore, one-third useful and two-thirds waste work.

[*A series of interesting diagrams drawn by a recording dynamometer accompany the original paper and clearly demonstrate the distribution of power.—ED.]

Room No. 2—This room contained the following machinery and shafting:

Shafting, 2 inches in diameter and 85 feet long; 311 revolutions per minute.

Twelve journals on main shaft, three of them roller bearings.

Thirty-four belts of an average width of $1\frac{3}{4}$ inches.

Eleven small automatic screw machines.

Two milling machines, 8 inches by 24 inches.

Seven engine lathes, 13-inch and 14-inch swing.

Two turret lathes.

The test began at 6.40 A. M. and continued until 4.55 P. M. In this case about twelve machines were running most of the time, but the load was variable. The total average power used was 8.93 H.P., of which 2.84 H.P., or about 32 per cent., was consumed by the shafting and belts.

Room No. 3.—This room contained shafting and machinery as follows:

Shafting, 75 feet long, 146 revolutions per minute, nine journals.

Nineteen belts having an average width of 3 inches.

Three special lathes. Nine drill lathes.

One engine lathe. Three drill presses.

Horizontal drill grinder, emery wheel, etc. The average number of machines running was five, and the load was extremely variable. The test began at noon and lasted until 5 P. M. The total power used was 2.31 H.P.. of which 1.33 H.P. was consumed by shafting and belts, or a loss of 57 per cent.

The experiments on these three rooms show about what may be expected in ordinary practice, when no special effort is made to keep all the machines in operation or to load them to their full capacity.

In April, 1899, a test was made at a pattern shop to show the power consumed by wood-working machinery. The following list indicates the shafting and machinery tested:

Shafting, $1\frac{5}{16}$ inches in diameter, 70 feet long, 294 revolutions per minute.

Thirteen belts, having an average width of 2.32 inches.

Five journals on main shaft, 8 feet apart.
Seven wood-turning lathes, 10-inch to 14-inch swing.
One patternmaker's gap lathe.
One band saw, 36-inch wheels.
One circular saw, 8-inch.
One buzz planer, 14-inch head.
A summary of the results of several tests is subjoined :

	Horsepower.
Buzz planer, empty	0.81
Buzz planer, cutting	1.51
Circular saw, cutting	0.80
Band saw, cutting	0.22
All machines, cutting	3.70
Shafting and belts	1.87
Shafting alone	0.67

These experiments show the following distribution of power :

	Horsepower.	Per cent.
Shafting alone	0.67	12
Belts and Pulleys	1.20	22
Machines, cutting	3.70	66
Total	5.57	100

In a series of experiments made in 1895–96, and first reported to the American Society of Mechanical Engineers, the writer determined the power losses in twelve different machine shops. In six shops using heavy machinery the average power consumed by engine, shafting and belts was 62 per cent. of the whole, and in six shops using light machinery 55 per cent. was the average loss. Nearly all the shops were running at what they called full capacity.

Table III shows the distribution of the waste and useful horsepower in ten of these establishments. The friction horsepower per counter shaft is quite uniform in these different cases, being about 0.6 H.P. for the heavy work and 0.2 H.P. for the light work. The useful horsepower per machine naturally varies considerably, but averages about 0.5 H.P. per machine. This corresponds well with the figures that have been given previously.

TABLE III.

Nature of work.	Friction horsepower.				Useful H.P. per machine.
	Per bearing.	Per counter.	Per belt.	Per cent. of whole.	
Boiler shop	0.550	0.538	0.477	65	0.310
Bridge work	0.337	0.606	0.521	80	0.164
Heavy machinery	0.581	0.665	0.453	57	0.707
Heavy machinery	0.799	0.600	0.475	54	0.627
Average	0.567	0.602	0.481	64	0.452
Light machinery	0.204	0.155	0.095	51	0.790
Small tools	0.689	0.127	0.119	54	0.809
Small tools	0.240	0.121	0.113	52	0.881
Sewing machines	0.397	0.269	0.208	57	0.180
Sewing machines	0.406	0.172	0.154	69	0.181
Screw machines	0.633	0.291	0.235	47	0.296
Average	0.428	0.189	0.154	55	0.406

After studying these apparently excessive losses due to the ordinary system of transmission by belts and pulleys, one naturally turns to electrical transmission for relief. It is not best, however, to be too sanguine in regard to the newer way. The experiments made in the locomotive works, which have been already referred to in this article, show the power consumed by heavy machine tools when driven by independent motors.

An average of sixteen tests on different lathes, planers, slotting machines and boring mills gives 8.85 H.P. for the machine and work, and 2.35 H.P. for the motor and counter shaft. Thus, we see that when the machines were run under the most favorable conditions, the motor and its shaft consumed nearly 25 per cent. of the total power used, which is fully as much as would be lost in well-constructed line and counter shafts.

When the group system of electric driving is resorted to for smaller machines, we have a mixture of the old and the new. Table IV gives a summary of the principal results obtained from tests of machine tools where these were driven in groups by electric motors.

We may, then, safely predict a loss of at least 25 per cent., whether wires or belts and shafting be the transmitting agent. The extraordinary losses shown by some of the shops referred to in Table III, were due in most cases to an excessive use of

TABLE IV.

Length of line shaft in feet	60	100	60	80
Diameter of line shaft in inches	$2\frac{3}{16}$	$2\frac{7}{16}$	$2\frac{3}{16}$	$2\frac{3}{16}$
Speed of shaft, revolutions per minute	150	150	150	150
Number of machines	13	23	17	8
Total horsepower	34.2	40.7	31	21.9
Horsepower of motor and shafting	15.1	12.1	88	5.8
Horsepower of machines	19.1	28.6	23	16.1
Average horsepower per machine	1.47	1.24	1.35	2.01
Per cent. of total horsepower for motor and shafting,	44	30	25.8	26.5

line shafting, one establishment having nearly 1,500 feet of shafting to drive 70 machines and losing 80 per cent. of the power on its way. In some cases the alignment and general condition of the shafting was poor.

The principal arguments for the introduction of electrical transmission have not to do with saving of power, and may be thus summarized:

1. Better arrangement of machinery to facilitate handling of work.

2. Clear head room for the use of electric cranes and small hoists.

3. Light and cleanliness.

4. General flexibility of the system for changes and extensions.

5. The use of electricity for other purposes than power.

OBJECT LESSONS.

By Lieutenant Commander A. B. Willits, U. S. N.

1. *Bearing Metals.*—In modern machinery design the most ample proportions are given to the main journals of steam engines in order to secure the desired speed of rotation without overheating and with only a moderate and economical lubrication. Unfortunately, however, in the case of the machinery of our naval vessels, this moderate lubrication falls to the management of the engineer who takes charge of the plant subsequent to the builder's trials, for no limit is placed upon the quantity of lubricating oil to be used, or actually used, during the full-speed runs before acceptance.

Reports of these trials may indicate that no excessive heating of the journals occurred, and that "only slight streams of water" were kept running on them as a precautionary measure. Consequently, as the work of turning out for examination a large number of bottom brasses is a work of considerable difficulty, and involves a material expense and delay, it is not usually demanded by the trial board where no evidence of defect is made apparent during the trials.

When, however, later on in service, and prior to any repetition of the severe tests given on the official contract runs, the brasses are overhauled for adjustment, it is not an unusual thing to find many of them more or less scored or pitted, and the actual bearing surface thereby considerably reduced from that designed. Of course, these discoveries are generally followed by a direct assertion that the journals had become overheated on the official trial. Further criticisms are also evoked on the composition of the lining metal, but as all the evidence is circumstantial, the matter seldom comes to official light.

To officially limit the amount of oil to be used on the bearings of a naval vessel on her contractor's trial would create what

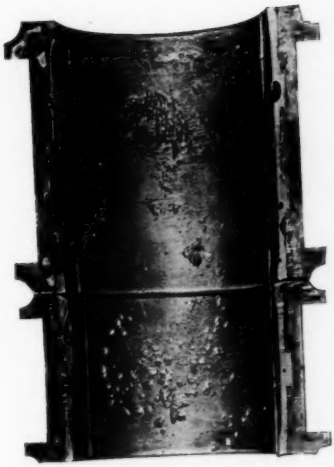


FIG. 1.

might be termed "anxiety," to say the least, and would be met with the reminder that newly-machined journals must have abundant lubrication until they become worn down to good-running surfaces, and that an economical limit is not possible until this is accomplished. Practically this is not true, as anyone knows who has followed the construction of high-class marine machinery at the works of our own builders and remembers the admiration he felt and expressed at the perfection of finish and surface given to these principal supporting points, both on journal and lining metals of brasses, as they are prepared for the maiden ordeal which decides the highest speed of the ship. Seldom thereafter will these journals be found more highly polished or more uniformly distributing their pressure on the brasses.

As regards the question of lining metals, more can be said. Not that there are few good compositions from which to choose, for the possibilities of securing patents on closely-allied mixtures are obvious, and have resulted in more brands and claims than in fortunes for their inventors. Granting, therefore, a good composition, there is a point too frequently lost sight of which has a most important influence on the result in use, and this is the manner of mixing and casting.

In the tin-copper-antimony mixture, such as is considered standard by the Bureau of Steam Engineering, there is danger in adding the tin too soon or at a too high temperature. Indeed, it should not be added until the pot has been removed from the furnace, and then the whole should be quickly covered with charcoal, while the tin is dissolving. Antimony tends to coarse crystallization, but properly handled, and in small proportions, it is a very satisfactory alloy.

Fig. 1 illustrates a condition of lining metal, the prototype of which is familiar to most naval engineers. Evidently local heating, induced by lack of uniformity of the metal, has resulted in the pitting shown, hard spots rapidly increasing the friction at such points. This non-uniformity may be attributed to either segregation or coarse crystalline structure.

Mr. Robert Job, the chemist of the Philadelphia and Reading

Railway, contributes an interesting article to the February "American Engineer and Railroad Journal," on "*Some Causes of Excessive Heating in Bearing Metals*," and alludes to the effect of coarse crystallization as creating such local heating, owing to the varying degrees of hardness.

The article noted is one of a number recently written on the subject, and it appears that both in this country and in Germany a coincident interest is being taken in this field.

The use of the microscope has enabled enquirers to determine specific causes for such overheating which, heretofore, have been more or less conjectural. The conclusions of the investigations point to the following as the main reasons why local overheating occurs.

Coarse crystalline structure.

Segregation of the ingredients.

Excessive inclusion of gases or of dross.

The lack of proper lubrication should be included, though investigation seems to show that a relatively small percentage of the bearings examined had been discarded owing solely to this particular cause.

Segregation, it is stated, has been found to be due in many cases to an attempt to alloy the metals in improper proportions, this being notably the case in some of the copper-tin-lead compositions in which an excessive proportion of lead had been introduced, resulting in the liquation not merely of a portion of the lead, but often also that of a part of the copper into "copper spots," thereby producing surfaces of relatively high heating capacity, and ultimately causing "hot boxes."

It is possible to prevent to a certain extent these segregations in a wrongly-proportioned composition by a rapid chilling of the metal immediately after pouring. As such practice is at the expense of the ductility of the metal, and causes an increase in brittleness, with consequent rapid wear in service, it is not recommended. Overheating, combined with rapid pouring and feeding, is also a common cause of segregation, as under such conditions the metal in the mould remains for a considerable time in a molten condition, and by chilling gradually is given the

greatest possible chance to solidify in definite natural alloys, throwing out whatever excess of metal may be present beyond these proportions, and thus resulting in segregation.

Attention is called to the practical effect of these segregations, for it is evident that instead of an alloy of uniform hardness and heating capacity there is a mixture, some portions of which are relatively very hard and others very soft, and this difference, combined with that occasioned by the varying heating capacity of the different portions, naturally localizes friction and ultimately results in excessive heating. In a homogeneous alloy or composition no such conditions exist, and while, as is true of some compositions, some of the metals may be present, at least in part, in mere mechanical mixture and not as a definite alloy, yet the particles may be made so small by proper foundry practice that the friction throughout the bearing is practically uniform, and undue local heating is not liable to occur, excepting through some outside agency.

Coarse crystalline structure which appeared in many defective bearings examined, was in some cases attributable to the composition of the alloy, antimony especially tending in this direction. In many cases, however, it has been traced to the foundry practice, often being due to rapid pouring at high temperature. Crystallization was also caused in some cases by the presence of an excess of various materials which were originally added as deoxidizing agents. Phosphorous and silicon are good examples. These, if added in suitable proportions, depending upon the condition of the metals, effect cleansing and free the metal from a large proportion of its enclosed gas, adding greatly to the fluidity and thus rendering the casting less porous, and at the same time increasing strength and ductility often to a marked extent, correspondingly increasing the capacity for wear. Excess of these materials beyond the amount required for deoxidation appears not to be thrown off from the metal in the form of oxides very appreciably, but causes crystallization.

In noting this coarse crystallization in the bearing, special attention is called to increased local heating, which results in the same manner as in the case of segregated bearings, owing

to the varying degrees of hardness and heating capacity of the constituents, while at the same time the ductility of the metal and the tensile strength are materially decreased. As the rapidity of wear with a given strength has been proved repeatedly by different experimenters to increase with the brittleness, it thus becomes evident that the durability of one of these crystallized bearings in service is bound to be defective owing to an excessive rate of wear, even though the heating which would naturally result should not occur.

A serious and easily avoided cause of trouble is the presence of particles of dross or oxidized metal mechanically enclosed, and also of large amounts of occluded gas in the metal. In the former case a hard cutting surface was presented to the journal, causing increased friction and hence heating. The presence of occluded gas in excess also tended in the same direction by reducing the actual bearing surface of the brass.

Heavy Forgings.—Fig. 2 shows a solid (?) steel forging, which was worked under too light a hammer. It was bored out and then machined in half in order to observe the effects or defects carefully. The illustration needs but little explanation other than this, the surface obviously being drawn out without really forging the interior of the mass. With the present methods of hydraulic squeezing there is little chance of lack of pressure being delivered to the core of even the largest masses forged, but where steam hammers are used it is well to remind the users of the futility of "sending a boy to do a man's work."

Copper Piping.—Fig. 3 illustrates the still common deterioration of copper piping on shipboard. Notwithstanding the number of years during which this has been going on, there remains uncertainty regarding the cause and a continued search for a remedy. It appears that electrolysis must have its potent yet mystic finger in the brew, as was pointed out some years ago by the Engineer-in-Chief, for the trouble seems to have only begun in earnest with the installation of electric-lighting plants on our metal ships.

Consistent and persistent experiments along well-thought-out

FIG 2.

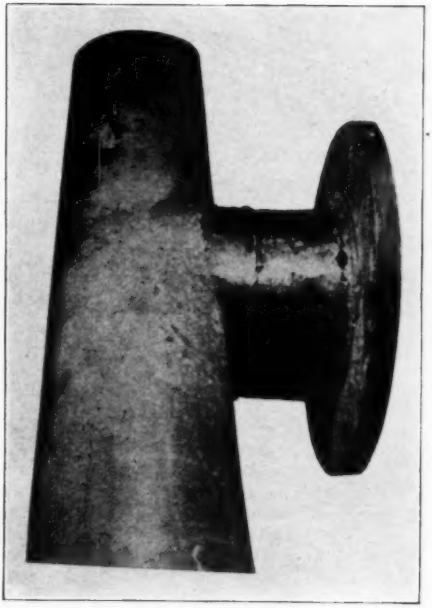


FIG. 3.

lines have been planned, but owing to exigencies of the service with ships in commission, the necessary overcrowding of the engineer officers with multifarious duties, the varying and constantly changing conditions under which duty of vessels is directed, have made thus far progress toward a solution of the problem extremely slow.

To those who cannot see the existent difficulties in the way of fuller experimental work, we can only say that neither interest or purpose are lacking—the means alone, at least at present, being unobtainable.

Individual experiments, on a minor scale, have been made on certain vessels in the line of insulating sections of piping theretofore evidencing rapid deterioration, and while unofficial reports have indicated either great improvement, or at least lack of further defective showing, the element of time has not been satisfactory, and track frequently lost of the experiments when the officers originating them were detached.

The rapid "corrosion" of condenser tubes has been a most expensive result of this mysterious action of the elements. When it costs from five thousand to ten thousand dollars to retube a pair of main condensers, the durability of the tubes is a matter of vital import. Here again is the irrationality of the "agent" visible, for on some ships under exactly similar service of both condensers, the tubes of one condenser will continue to "go" while those in the other condenser will remain intact—no difference being in the material of the tubes. The question has been considered of insulating such a condenser from the hull and all connecting piping, placing non-conducting liners under the supporting frames and insulating the attaching bolts by non-conducting thimbles and washers; all attached piping to be similarly insulated. While this is possible, we still have the steam link through which stray currents may enter unchecked and effect a mischief.

With condenser tubes as well as copper pipes, tinning does not seem to be a preventive; neither does the particular composition, from pure copper to Muntz metal, save the pipes or tubes.

It is a fact that steam piping does not come in for the attacks of the invisible enemy, but only piping in contact with sea water.

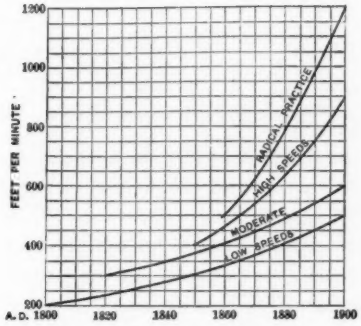
For cold water suction pipes a remedial application is found in cleaning the interior and coating it with hot asphalt or pitch, but full and satisfactory reports are still in the future regarding the permanency of the coating and extent of its protection.

For condenser tubes, limited experiments with an alloy of nickel point to a possibility in that direction which is to be further looked into, as, while the cost of the alloy is *apparently* prohibitive, it is only so and not *real*, as, when the frequency of renewal is considered, it would pay to buy tubes of pure silver if they would prove to be permanently efficient.

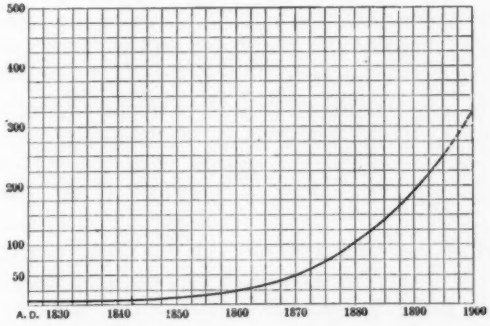
It is suggested that a deeper personal interest be taken by the individual engineer on shipboard in tracing the cause of this trouble and in reporting the effects of the methods he may adopt in attempting to remedy it. With careful work on the part of many, following such suggestions as they may conceive to be best, much light may be secured that will be helpful in speedily illuminating the particular dark spot in question.

Steam Engine Progress.—The present object lessons may be allowed the inclusion of a few of the curves which Dr. R. H. Thurston presents to the readers of "Cassier's Magazine" of January issue.* They are so graphic and lead us to such unavoidable conclusions that they are really the best kind of object lessons. Dr. Thurston's article will be widely read by engineers, yet we venture to reproduce here two of the simpler curves to give an indication of the character of the illustrations which abound in the article itself. From them one can foresee the great probabilities, and, as Dr. Thurston remarks, we may expect within a very few years to see steam pressures for engines of high efficiency mount to 1,000 pounds per square inch. What prophet can delineate the steam engine of the year 2000? What a world of possibilities is contained in the conception!

* "A Century's Progress of the Steam Engine."



MARINE ENGINE PISTON SPEEDS – 1800-1900.



STEAM PRESSURES IN MARINE ENGINES.

NOTES.

THE MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The Twentieth Annual Meeting of the American Society of Mechanical Engineers was held, December 5 to 7 last, at the Society's House. The opening session was held on Tuesday evening, at which time the President, Admiral George W. Melville, U. S. N., delivered an address on "Engineering in the United States Navy." The first session for professional papers was on Wednesday morning. The report of the council, presented by Secretary Hutton, showed a roll of 15 honorary members, 1,417 members, 123 Associates, and 402 Juniors, a total of 1,957.

Mr. Geo. H. Barrus submitted the final report of the Boiler Trial Committee, which was accepted and the committee discharged.

The tellers announced the election of the regular ticket, which was as follows: President, Mr. Chas. H. Morgan. Vice-Presidents, Messrs. E. D. Meier, Geo. R. Stetson, B. H. Warren, Jesse M. Smith, Stevenson Taylor and David Townsend. Managers: Messrs. Geo. Richmond, Jas. B. Stanwood, H. H. Suplee, E. C. Felton, A. M. Goodale, R. H. Soule, F. H. Boyer, Jno. A. Brashear and Alfred H. Raynal. Treasurer: Mr. Wm. H. Wiley. Secretary: Prof. F. R. Hutton.

The proposed European trip was then described by Mr. Henning, who stated that members and their families to the number of about 500 had signified their intention of going, and some hundred more might do so. The only steamer which could be secured to cary 500 was *Fuerst Bismarck*, of the Hamburg-American Line, which was booked to sail the last of May. No defininite arrangements had been made. It is probable that a meeting will be held in Cincinnati in May, even if a party goes to Europe.

The first paper presented was called "The Steam Engine at the End of the Nineteeth Century," and was from Dr. R. H. Thurston. It described the quadruple-expansion Nordberg pumping engine, built for the Pennsylvania Water Company and erected near Pittsburg, and gave the results of the test of the pump made by Professor R. C. Carpenter. The paper contained the table of pumping-engine performances prepared by Mr. George H. Barrus for the New England Water-Works Association, and also data prepared by Professor Unwin and Mr. Bryan Donkin concerning recent tests of economical steam engines. Dr. Thurston compared in a most interesting manner the experimental data with the working of the ideal engine of Carnot, and traced the reduction of wastes which has followed the advance in knowledge of engine construction.

In the discussion of the paper Mr. Charles T. Porter raised an objection to its title on the ground that a year must lapse before the end of the century, and during that time he expected to bring out an engine which would operate with 9 pounds of steam per horsepower per hour. He therefore requested Dr. Thurston "not to seal up his paper, but leave him a place on the last page." Mr. Porter proposes to use a steam pressure of 300 pounds per square inch to expand to 10½ pounds absolute, to use a piston speed of 1,200 feet per minute and to jacket the heads, barrels, ports and pistons of his engine with steam.

The next paper was by Professor C. V. Kerr, of the Armour Institute, Chicago, and discussed the Berthier method of coal calorimetry. The Boiler Trial Committee recommended the use of the Mahler calorimeter for determining the heat value of fuels, but admitted that the apparatus was complicated and expensive. The Berthier method, the author believed, is much simpler and less expensive. In it the coal is heated in a crucible with oxide of lead. The combustible constituents of the coal unite, in burning, with oxygen obtained from the oxide of lead. From the weight of reduced lead found in the crucible at the completion of combustion, the amount of oxygen required for combustion can be calculated. The heat value of

hydrogen and carbon in the fuel being different, it is necessary to determine how much of the oxygen obtained from the oxide of lead was used to oxidize the hydrogen and how much to oxidize the carbon, and for that reason the Berthier method is uncertain unless the amount of carbon and hydrogen in the fuel is known. The author derived the general formula that F pounds of fuel will evolve $423.4L \div F$ heat units per pound, in which L equals the weight of metallic lead reduced, and F equals the weight of fuel used. The author found by calculation that the heat value of a fuel containing 2 per cent. by weight of hydrogen, as in the case of coke, charcoal or anthracite coal, if determined by the formula, would be in error; so the formula was modified to $P = 434L \div F$. If the fuel contains an average of 5 per cent. hydrogen, as in the case of bituminous coal, lignite and wood, the formula, according to the author should be $P = 450L \div F$. The author believed the percentage of hydrogen in the fuels named is so nearly constant that the formulas are probably within $1\frac{1}{2}$ per cent. of their absolute accuracy.

Prof. J. H. Kinealy submitted a written discussion, in which he seemed to have a very poor opinion, to say the least, of the Berthier method.

"Tests of Two Pumping Engines at St. Louis Water Works," by Mr. J. A. Laird, was the next paper. This paper, and the two following it, "New Graphic Method of Constructing the Entropy-Temperature Diagram of a Gas or Oil Engine," by Prof. H. T. Eddy, and "Pressure in Pipes Due to Stoppage of Flowing Liquid," by Mr. George M. Peek, were not discussed.

On Wednesday afternoon several excursions were planned. One party visited the works of the Hewes & Phillips Company, in Newark, where several Diesel motors are being constructed, and one of them was shown in operation. Colonel Meier conducted this party. Quite a number visited the new power house of the Metropolitan Street Railway Company at Ninety-sixth Street and East River, New York.

On Wednesday evening a paper by Mr. A. L. Rice, on "The Liquefaction of Gases," was first read. This was followed by

two descriptive papers by Professor P. M. Chamberlain, entitled "A Curved Glass Blue Print Machine" and "A Metal Dynagraph."

"The Education of Machinists, Foremen and Mechanical Engineers," by Mr. M. P. Higgins, formerly superintendent of the Washburn shops of the Worcester Polytechnic Institute, led to a discussion which lasted nearly the entire evening. It covered so broad a field that it is impossible to give an abstract here.

On Thursday morning the first paper read described "An Experiment on Using Gasoline Gas for Boiler Heating." Its author was Mr. Herman Poole. A horizontal tubular boiler containing 520 square feet of heating and 111 square feet of superheating surface was fired with gasoline gas. Thirty-five gallons of oil, or 227.5 pounds, were consumed in about two hours in evaporating 1,000 pounds of water.

"The Friction of Steam Packings" was the subject of a paper by Prof. C. H. Benjamin, of Cleveland, who had made a series of tests of different kinds of packing used in the stuffing boxes of piston and valve rods. His conclusions were: That the softer rubber and graphite packings, which are self-adjusting and self-lubricating, consume less power than the harder varieties. The old braided-flax style gave very good results. That oiling the rod will reduce the friction with any packing. That there is almost no limit to the loss caused by the injudicious use of the monkey-wrench. That the power loss varies almost directly with the steam pressure in the harder varieties, while it is approximately constant with the softer kinds.

Prof. F. C. Wagner's paper on "Friction Tests of Locomotive Slide Valves" was then read, and this was followed by a "Note on Fly Wheel Design," by Mr. A. J. Frith. This was discussed at the same time as a paper by Mr. James McBride, describing "A Broken Fly Wheel and How It Was Repaired." The wheel described in Mr. McBride's paper is one of the band-wheel type, 26 feet in diameter, 90 inches face, and weighing about 35 tons. The ring was composed of 10 segments attached to the arms at the center, and bolted together at their ends between the arms, each arm carrying a segment. The ribs were four in number and cast on the inner face of the rim. In the middle of each

rim section a flat plate was cast on the inner ribs and a similar plate, cast on the outer end of the arm, was bolted to this plate. In 1889, an accident to the governor allowed the engine to race, and when it stopped, the ribs on the rim segments were found to be cracked in a number of places at their junction with the flat plates mentioned.

The author believed the cracks had been caused by the strains in the metal due to that part of the rim between the arms being forced outward by centrifugal force. Careful examination of these cracks during the last ten years did not show that they were extending, but, as the rim was running out of true, it was determined to strengthen the wheel, and, if possible, restore it to its true running condition. This was done by fastening the segments of the rim to the hub by means of $\frac{3}{8}$-inch steel plates, one bolted on each side of the flange where the segments are joined, connected by two iron tie rods with turnbuckles to triangular plates fitted over the heads and nuts of the bolts binding the arms to the hub. Triangular-shaped pieces of steel were punched so that they slipped neatly over the heads and nuts of the bolts on the hub, and fitted close to the sides next the shaft. These plates were fitted in pairs and held in place by a $\frac{3}{4}$-inch bolt passing through them just outside of the hub flanges. They were held apart by a separator $2\frac{1}{2}$ inches in diameter, with the ends turned down to take eyes of the tie rods and plates, and were held by nuts on each end. The outer ends of the tie rods were secured to the steel plates at the rims by eyes and turned bolts. When the turnbuckles were adjusted the wheel was in perfect balance. It was assumed in proportioning the apparatus added to the wheel that all those parts of the rim lying between any two arms were entirely broken loose from the rest of the rim and its centrifugal force at normal speed held by the two tie rods. The cost of the repairs was $500.

The papers on fly wheels led, as usual, to a long discussion. Mr. Charles T. Porter said that the proper way to construct a safe fly wheel was to use thick sections and cool them slowly after casting to avoid shrinkage strains. Mr. Boyer said that all accidents he had seen were due more to the foundryman than to the

designer. He spoke of digging putty out of a large hole in the arm of a pulley recently purchased.

The next paper read described an "Efficiency Test of a 125-Horsepower Gas Engine." The author was Prof. C. H. Robertson, of Purdue University, and an abstract of it appeared last week. In the discussion Mr. E. Rood pointed out that the engine was not operating under conditions likely to secure the highest efficiency. Dr. Thurston stated that the theory that the loss of heat due to jacketing the cylinder increased with the size of the engine was verified by this test, but that the loss of heat in the exhaust gases had been correspondingly reduced, thus bringing about the usual efficiency.

"The Strength of Steel Balls" was then discussed in a paper by Mr. J. F. W. Harris. It described a series of tests made at the Rose Polytechnic Institute on the strength of steel balls. A table showing the breaking strength was given. Mr. Gus. C. Henning pronounced the paper entirely valueless, because the crushing strength has nothing to do with the design of balls for a bearing, but that the yield point was the thing to investigate.

The last paper of the session discussed the "Colors of Heated Steel at Different Temperatures." Its authors were Messrs. Maunsel White and F. W. Taylor, of Bethlehem, Pa. In discussing it Mr. William Metcalf objected to the use of the word red to describe the color of steel, for the reason that he believed heated steel was not red. The true colors were more on the orange and lemon order. There seemed to be a quite general opinion among those discussing the paper that the determination of the temperature of steel from its color would result in a great difference of opinion on account of the different sensations that a color produces upon the eyes of different individuals.—"The Engineering Record."

TESTS OF A REFRIGERATING PLANT.

An interesting series of tests of the refrigerating plant in the steam engineering laboratory of the University of Wisconsin was printed in a recent issue of "The Wisconsin Engineer." The

tests were conducted by Messrs. Walter Alexander, William H. Kratsch and Wallace F. MacGregor, and their report is prefaced by a historical review of the development of the refrigerating process. Extracts from this, which will doubtless prove of interest, have been made, and an abstract of the tests follows.

In the year 1550 Blasius Villafranca, an Italian physician and scientist, discovered that artificial cold was produced by dissolving saltpetre in water. In 1607 Satinus Tancredus, also an Italian, found that very low temperatures could be obtained by mixing saltpetre with snow. The first ice machine of which there is any record was invented by Dr. Cullen in 1755. This machine embodied what is known as the vacuum principle, and was the pioneer of all those subsequently designed for cooling and freezing liquids by evaporating part of them in vacuo. Dr. Cullen found that by reducing the atmospheric pressure with an air pump the evaporation of water could be increased sufficiently to cool it enough to form ice.

In 1777 Nairne found that by letting the air pump exhaust into sulphuric acid the vapor would be absorbed from it and the air could be used again. He was able by means of this discovery to construct, in 1810, an apparatus in which the freezing went on continuously. About this time Leslie, the later Kingsford, experimented with similar apparatus, but with little success.

The first patent granted on ice machines was obtained by Vallance in 1824. His apparatus consisted of shallow pans containing water, over which a current of dry, rarefied air was circulated. The vapor absorbed by the air in passing over the pans was removed by sulphuric acid. The air after being dried was ready to take up more moisture and so the process of freezing was continuous.

The compression system was first used in 1834 by Jacob Perkins. He used ether, which was compressed by a pump and cooled with water until it was condensed. It then passed to expansion coils, where it was vaporized, absorbing heat in so doing. From the expansion coils it was drawn back to the pump and used over again.

Perkins' machine was only experimental, and it remained for

Professor Twining, of New Haven, to devise and construct the first machine to manufacture ice for actual consumption. After some years of experimenting with sulphuric ether, with a view to producing ice in quantities, Professor Twining took out his first patent in England in 1850. Three years later he was granted a patent in the United States, and in 1855 had a machine in operation at Cleveland, Ohio. He used a double-acting vacuum and compression pump 8½ inches in diameter and 16-inch stroke. The cistern from which the heat of expansion was absorbed contained a liquid that would not freeze at ordinary temperatures. In this liquid iron molds filled with water for freezing were immersed. Professor Twining discovered among other things that ice frozen at a temperature slightly below the freezing point would be transparent, except the core, while if frozen at lower temperatures the ice cake would be opaque and porous throughout. The Cleveland machine was designed to produce 2,000 pounds of ice in 24 hours, but 1,600 pounds was the highest amount recorded.

In 1851 Dr. John Gorrie, of New Orleans, after years of experimenting, obtained a patent on a refrigerating machine, using air as the cooling fluid. He reasoned that, as an increase in temperature of several hundred degrees was obtained by compressing air to four or five atmospheres, on allowing it to expand after it had assumed the temperature of the surrounding air a decrease in temperature would be in inverse ratio to the original increase. The air, after compression, was led through a coil in the cooler to a reservoir, where it was admitted to an auxiliary pump. This auxiliary pump was driven by the expansion of the air. Its cylinder had a jacket through which a circulation of brine was maintained. The brine was cooled by the expansion of the air in the pump cylinder, and in turn reduced the temperature of the ice-making tank. The air being damp after compression and imperfectly cooled, prevented the machine from working in a satisfactory manner. Dr. Gorrie's experiments were valuable in that they demonstrated that cold could be produced with air without the aid of chemicals.

In 1852 Edmund Carre improved Vallance's vacuum appara-

tus so that it was used to some extent in the Parisian cafés and restaurants for making ice and cold drinks. James Harrison, in 1856, designed the first machine for making ice for commercial purposes in England. He used sulphuric ether, and his machine embodied the principles of that of Perkins.

The ammonia-absorption system in use to-day was introduced by Ferdinand Carre, brother of Edmund previously mentioned, in 1858. In this system the ammonia is obtained from an aqueous solution by heating in a boiler or still until the ammoniacal gas is driven off, the distillation causing the pressure to rise, and the gas, together with 10 per cent. of steam, passing to the condenser, where it is changed to the liquid form. The gas from the expansion coils passes back to the absorption chamber, where it is taken up by the weak solution of ammonia. The 10 per cent. of moisture carried over from the still absorbs the ammonia, and as water can take up 700 times its volume of ammoniacal gas this loss amounts to considerable. Then, too, the water fills up the pipes of the condenser and thus lessens the refrigerating power of the machine. On the other hand, the absorption system has an advantage in that the bulk of the heat required for performing the work is applied direct without being transformed into mechanical power.

In 1863 Dr. Alexander Kirk produced a cold-air machine embodying important improvements over that of Dr. Gorrie. This machine consists essentially of a compression pump, a hot chamber, a displacer piston and regenerator, and a cold chamber. The hot and cold chambers form the two ends of a cylinder in which the displacer piston works. The operation of the machine is as follows: The pump forces air into the hot chamber, the heat being carried away by circulating water. When cool the air is moved by the displacer piston into the end of the cylinder forming the cold chamber. The compression piston now moves outward, expanding the air in the cold chamber and producing a very low temperature. The brine or other liquid to be cooled passes through this cold chamber. The machine worked up to a pressure of 200 pounds per square inch, and a temperature of 39 degrees Fahrenheit was obtained.

In 1869 a cold-air machine adapted to compress air in stages was invented by Merchant.

In 1870 Carl Linde obtained the first patents on compression machines, using ammonia as the cooling fluid. His machines gave very favorable results, and were used in Germany for some years. Gifford used cold air in his machine. In 1873 he had one in operation in which a spray of water mingled with the air in the compression cylinder, the water being vaporized by the heat of compression. The discharge valve from the expansion cylinder was located in the piston and so adjusted that it would open when the pressure in the cylinder fell below a certain point, allowing the air to pass through to the other side of the piston, and afterward to the refrigerator. In the same year Postle designed a machine which was practically a modification of Kirk's cold-air machine.

The improvements introduced in cold-air machines in 1877 by Bell-Coleman added very considerably to their practical value. This invention comprised a means for cooling the air both in and as it left the compressor by jets of water, and for drying it again before it passed into the expansion cylinder. On leaving the compressor the moist air passed through a chamber with perforated diaphragms, and was then conducted to the expansion cylinder through coils having a very extended surface and cooled to a temperature lower than that of the cooling water, thus causing a deposition of the moisture.

In 1878 James Harrison took out a patent on a vacuum apparatus designed to produce ice at a very low cost. He succeeded in making what was considered a poor quality of opaque ice at about one shilling per ton. In 1878 Frantz Windhausen, of Berlin, patented a machine on the vacuum principle for producing ice on a large scale without the use of sulphuric acid, also an arrangement in which sulphuric acid was used, the acid being cooled by water during its absorption of the vapor and afterward concentrated so that a fresh supply was not required. An improved form of Windhausen's machine was constructed in 1881 capable of producing 15 tons of ice in 24 hours. It was first

put up at the Aylesbury Dairy, Bayswater, London, and afterward removed to Brompton.

In 1880 Lightfoot introduced an improved cold-air machine in which the expansion was performed in two stages. The advantage of this was that the air could be made to deposit most of its moisture during the first expansion, and then the dried air further expanded to the required temperature and pressure. The compressed air is passed into a small primary expansion cylinder. In this it is expanded beneath the piston to a pressure that will give a final temperature of about 35 degrees Fahrenheit. By this means almost all the vapor held in suspension in the air is condensed and discharged, in the form of mist, with the air into a separator, upon the surfaces of which it is deposited and may be drawn off at the bottom. From the separator the dried air, still at a considerable pressure, is carried to the second expansion cylinder, in which it is expanded down to atmospheric pressure and passed out cold and practically free from moisture.

The same year that Lightfoot started his machine Sir Alfred Haslam brought out a machine with some important improvements over the Bell-Coleman machine, which it resembled. Raoul Pictet, in 1887, obtained a patent on an improved cooler. In this the volatile liquid is subjected to evaporation so as to reduce the temperature of the brine surrounding the evaporating compartments. Pictet used as a refrigerating agent a combination of carbon-dioxide and sulphur-dioxide. This fluid has a vapor tension much less than that of carbon-dioxide or even sulphur-dioxide at temperatures above 76 degrees Fahrenheit. It is known as Pictet's fluid.

De Motay and Rossi used as a refrigerating agent a mixture of common ether and sulphur-dioxide. It was found that at ordinary temperatures liquid ether has the power of taking 300 times its own bulk of sulphur-dioxide. At a temperature of 60 degrees Fahrenheit, the tension of the ethylo-sulphurous-dioxide, as it is called, is lower than that of the atmosphere.

During the last 20 years the development of refrigerating machinery has been very rapid. The application of refrigeration to steamship transportation may be said to mark an era in

the history of modern commerce. In 1881 the first cargo of frozen meat was shipped from Australia to England in the *Strathleven*, fitted with a Bell-Coleman cold-air machine. During the same year the *Protos*, fitted with a machine copied after one of Lightfoot's, and the *Orient*, with a Haslam machine, arrived in England with cargoes of meat in good condition.

The machine used in these tests was built by Geo. Challoner Sons, Oshkosh, Wis., and was installed in the spring of 1898. It is of the compression type, using anhydrous ammonia as the refrigerating fluid, and is rated by the manufacturers at five tons capacity when running at 160 revolutions per minute. The compressor is vertical, having three single-acting cylinders connected to the same crank shaft and acting at 120 degrees. Each cylinder is 4½ inches in diameter, with a 6-inch stroke of piston. A brine tank was used to furnish the heat which is absorbed by the expansion of the liquid ammonia, the gas from the compressor having been previously cooled to the liquid state by means of the customary condensing apparatus. The compressor was driven by a 5½ by 7-inch vertical slide-valve engine.

Eight tests of four hours each were made, and they were conducted with a view of determining the comparative efficiencies with pressures of ammonia varying from 140 to 220 pounds, other conditions being kept as nearly constant as possible. One series of tests was carried on with the temperature of the brine tank at 32 degrees Fahrenheit, and another at 38 degrees, to determine what effect, if any, this change of temperature had on the efficiency of the machine. The temperature of the brine was kept constant by using steam in a coil in the tank.

Before beginning the tests the compressor was run about two hours to establish normal conditions. Indicator cards on compressor and engine were taken every twenty minutes throughout the tests. The quality of the steam was taken with a separating calorimeter, readings being taken every half hour. The amount of heat radiated was determined for the two temperatures used in the test by allowing the tank to remain for twenty-four hours and observing the rise in temperature. This amount of heat was added to the amount absorbed from the steam coil. Dur-

ing some of the tests there was a slight change in the temperature of the brine tank, and when this occurred a correction was made in the amount of heat absorbed. The amount of cooling water used in the condenser was weighed by means of two barrels and two pairs of scales. The steam used for maintaining constant temperature of the brine tank was weighed as it was discharged from the coil, and the cooling effect of the plant in British thermal units was determined by the amount of heat given up by this steam, corrections being made for radiation and change of temperature of the brine tank. This cooling effect, divided by the heat equivalent of the work done by the compressor plus the heat absorbed by the cooling water, determined the efficiency of the plant. The thermometer used for taking the temperature of the brine tank read to tenths of a degree centigrade. The density of the brine was determined by means of a hydrometer, and from the density the percentage of salt was obtained. The specific gravity at 48 degrees Fahrenheit was found to be 1.067, which corresponds to 8.1 per cent. solution; its specific heat was taken as 0.916.

Test.	Brine temperature.	Tons ice per twenty-four hours.	I.H.P. engine.	I.H.P. compressor.	Efficiency, engine and compressor.	British thermal units.					Efficiency, per cent.
						I.H.P. equivalent in four hours.	Cooling water.	Cooling water plus compressor.	Steam.	Net cooling effect.	
1	31.56	4.32	7.94	5.38	67.8	54,870	263,918	318,766	202,699	211,168	66.4
2	32.91	3.53	7.79	5.69	73.1	57,932	217,780	275,703	170,573	189,915	68.9
3	32.19	4.18	8.02	5.75	71.7	58,533	231,135	289,872	200,537	208,626	72.4
4	32.01	3.92	8.09	5.84	72.4	59,543	188,208	247,203	188,136	180,640	73.1
5	36.3	3.49	5.91	4.58	77.6	46,624	201,222	247,846	167,507	173,033	70.0
6	37.94	3.64	6.51	4.62	70.7	47,032	205,468	252,500	174,560	180,106	71.3
7	38.57	2.99	6.37	4.77	74.9	48,553	165,089	213,647	143,324	154,376	72.3
8	38.3	3.73	7.98	5.81	72.8	59,146	198,009	257,155	179,917	185,443	72.3

The results of the tests are shown in the accompanying table. The total heat units absorbed by the cooling water includes the amount of heat taken up by the compressor-jacket water. The experimenters concluded from these tests that the difference of

6 degrees Fahrenheit in the temperature of the brine tank in the two series of tests did not apparently affect the efficiency. The speed of the machine was variable, due to the governing of the steam engine, which was overloaded most of the time; this, it was thought, accounted for the variation in the cooling capacity of the plant.—"The Engineering Record."

ANNEALING ARMOR PLATES.

At the meeting of the Engineers' Club of Philadelphia, December 16, Mr. C. J. Dougherty, the superintendent of the electrical department of the Cramp shipyard, read an interesting paper on "The Electrical Process of Annealing Armor Plates in the Construction of Warships," which was illustrated with slides showing the way in which battleships are armored and the construction and application of the apparatus for annealing the plates. The armor plates are known as Harveyized plates, and are hardened on their surface to a depth of about seven-eighths of an inch, the hardness being so great that they cannot be drilled. In order to properly mount them, they must first be locally annealed in the spots where they are to be drilled, and after futile efforts to do this by other means, the electrical method was resorted to, and has proved to be so successful that it is now used entirely by those builders. In principle the apparatus is like the well-known Thomson electric welder, the ends of the secondary coils being held on the surface of the plate at the spot which is to be annealed; the secondary current therefore passes through the surface of that portion of the iron and raises it to a red heat, which draws the temper of the hardened shell. As the chilling action produced by the surrounding iron is great enough to restore the temper if the current is stopped suddenly, the current is reduced very gradually, from 10 to 20 minutes being allowed for this gradual diminution. The apparatus consists of a transformer, the secondary of which is made of a very large copper casting closely surrounding the primary, and both are surrounded by iron; the secondary is slit in one spot, and the two ends terminate in the contact points. The transformer is

surrounded with oil, and the terminals are kept cool by a flow of water through them. The ratio of transformation is 100 to 1, the primary current about 100 ampères at 300 volts, and the secondary about 10,000 ampères at 2.5 to 2.8 volts. The contact surfaces are only about half a square inch, and the current density at those spots is, therefore, about 40,000 ampères per square inch.

The total weight of the transformer is about 1,000 pounds, which, when resting on the plate, is sufficient to make good contact. Directly under these contacts the metal remains hard and cannot be drilled; the space to be drilled lies midway between the two contacts. The alternator, of which there is one for each transformer, is separately excited, and is driven by a continuous-current motor, which is connected to the continuous-current power mains running throughout the yard. These two machines together are transported to where the work is to be done. The annealing current is regulated by regulating the exciting current of the alternator, the rheostat for which is placed where the work is to be done; four wires are, therefore, required from the work to the generator. Two of these sets of annealers have been in use by the Cramps for some time. The plates for the *Alabama* were all annealed in this way. The Harveyized plates are now being superseded by the Krupp plates, which are hardened to a depth of two inches instead of only seven-eighths inch, but, notwithstanding this great depth, the electric method of annealing is found to answer very well for these also. The fact that the generating machinery, together with the whole shed which protects it, was transported about the yards to near the work, instead of running mains from a stationary plant, was explained by the statement that it was less trouble to transport this machinery than to run the wires. With the present system each transformer must have its own alternator and exciter, and in this connection the question arose in the discussion, why choking coils are not used in the secondary circuit instead, which would require the running of but two wires, and would enable both transformers to be supplied from the same alternator. The reason why this apparently simpler

method is not used was not explained.—"Electrical World and Engineer."

THE TALBOT STEEL PROCESS AT THE PENCOYD IRON WORKS.

Ever since September of last year, metallurgists have been watching, with much interest, the operation of the Talbot continuous basic open-hearth furnace at the Pencoyd Iron Works. This plant is a development of ideas which Mr. Talbot formed as the result of a series of experiments in desiliconizing pig iron at Chattanooga. The furnace at Pencoyd takes a charge of 160,000 pounds, but the inventor believes that a furnace on the same general design, but half again larger, would furnish steel at a still lower cost. In a recent issue of "The Iron Age" the process and plant was described at some length, and from that valuable article the following general description has been prepared.

The plant consists of an 80-ton open-hearth furnace of the Wellman tilting type, modified in some respects. It has a 30 by 10-foot hearth. Gas is admitted through a central flue flanked on each side by an air port, the combustion taking place in the furnace proper. The flue cages are mounted on wheels, from which they are lifted by hydraulic cylinders to make them register with the ports of the furnace. When the latter is to be tilted the gas is cut off, the cage is lowered to the wheels and withdrawn from the furnace on its track. The furnace is so arranged that it can be tilted either way. On the charging side there are three doors, one of which is fitted with a spout from which slag may be discharged. The other doors are arranged so that liquid metal may be run into the furnace. On the tapping side the metal can be drawn off at a level 3 or 4 inches below the cinder.

The furnace was originally supplied from a 120-inch cupola, discharging into a 15-ton ladle carried by an overhead electric traveling crane. A second cupola is being installed so that the melting capacity is increased to 40 tons per hour. With but one cupola it has been impossible to carry on the continuous process steadily with liquid metal. It was necessary to drop

the bottom of the cupola on Saturday night and spend Sunday and a part of Monday in repairs and relining, so that molten metal has not been available for the furnace until Tuesday morning. During the interval it has been necessary to charge the furnace with cold stock.

The process consists in adding to an initial bath of steel charges of molten pig iron or partly purified iron and charges of mill cinder or iron, to enrich the slag as oxidized, and withdrawing an aliquot part of the steel and of the slag whose oxidizing capacity has been exhausted. The process depends upon the desiliconizing, decarbonizing and dephosphorizing action of a highly basic, ferruginous slag upon molten impure metal. The reaction takes place during the passage of the molten metal through the liquid-enriched basic slag, and also through the contact of the impure metal with the supernatant slag, this being promoted by the fact that the incoming impure metal floats upon the finished purified metal constituting the great mass of the bath.

The first step in the operation of the furnace is the preparation of an initial bath, in the same manner as in ordinary practice. This bath is usually equal to 60 to 75 per cent. of the capacity of the furnace. A slag covering is created by the addition of mill cinder, iron ore and limestone. A dam of basic material is built across the slag runner, the furnace is slightly tilted so as to be higher on the charging side, the iron runner is placed in position at the second charging door, and liquid metal is then poured into the furnace, the gas having been cut off. In a brief time a very active reaction takes place, accompanied by the discharge of a large volume of carbonic oxide gas, which bursts from the doors and escapes through the flues into the checker work, which incidentally it helps to heat.

After the boiling has subsided some of the slag, whose capacity to oxidize the metalloids of the bath has become exhausted, is discharged from the furnace by tilting it, the slag flowing into a car beneath the spout. Then begins the work of again enriching the slag to bring it back to the requisite basic condition. This is accomplished by the addition of iron ore, mill cinder,

limestone, and sometimes manganese ore to take care of the sulphur. These alternate charges are repeated until the capacity of the furnace has been reached. Then a part of the steel is tapped, the quantity depending upon the usual charges handled in the casting pit of the works. The steel is tapped from a point several inches below the slag level, so that only clean metal is poured out. This does away with the mess attending the tapping of a whole charge of a furnace, and minimizes the danger of reintroducing phosphorus into the steel from the cinder during the recarburizing. The recarburizing is done in the ladle in the usual manner. In the journal from which these notes are taken there is a record of a typical charge throughout the entire course of the operation, which will be found of much interest to those who desire to trace the process in detail.

At the outset it was feared that the wear on the furnace might prove a serious obstacle, and that corrosion, particularly in the region of the slag zone, might be frequent and extensive. The tapping of a part of the bath and the subsequent additions of hot metal cause a fluctuation in the level of the bath of about 4 inches, and this is what may be termed a critical zone. Experience during the last five months has shown that these fears are unfounded. The practice is to repair the lining immediately after the tapping of a charge of steel, by throwing in a mixture of crude dolomite and 5 per cent. of resin. The presence of the bath of metal prevents the waste of material which takes place in patching the emptied ordinary open-hearth furnace by the rolling down of the material from the sides. Where repairs are most needed is at the jambs of the doors on the charging side.—"The Engineering Record."

THE STRENGTH OF RUBBER HOSE.

The introduction of steam heating in railway carriages has made it necessary to provide rubber hose connections which shall stand the rather severe duty of this peculiar service. In the case of air-brake hose the problem is confined to securing tightness against leakage of air under pressure, and endurance of

the wear and tear of operation and handling. For steam heating connections, however, there are effects of steam and the action of hot water to be considered, and experience has shown the necessity of providing strict specifications and exhaustive tests in order to insure satisfactory results.

A series of tests has recently been made at the Government Testing Laboratory at Charlottenburg, and the results are now made public in a paper in the "Mittheilungen" by Professor Rudeloff, and as the subject is one of international interest an abstract of his paper is here given.

The requirements of the German government for steam hose are very strict, and are in substance as follows:

The hose is to be made with five layers of pure linen with sheet rubber between, and is to be covered with linen. It must stand an internal pressure of 150 pounds per square inch, either hot or cold, without injury, and when subjected to internal pressure of 60 pounds for four hours should not twist. The rubber must be free from foreign substances. A temperature of 350 degrees Fahrenheit sustained for four hours should not affect the strength nor injure the hose in any way. The presence of hot water under pressure should not cause the linen to be easily separated from the rubber nor the layers of rubber from each other.

Holding these requirements in mind, the tests made by Professor Rudeloff may be considered in brief.

After a careful measurement and inspection of the samples they were subjected to an internal pressure of 150 pounds with water at the temperature of the air, with water at 170 degrees Fahrenheit, and with steam pressure. A pressure of 60 pounds was then maintained for three hours, and an inspection for defects then made, after which the sample was subjected to a heat of 350 degrees Fahrenheit, both with steam and with dry heat, and the strength of the material then examined. The adhesion of the linen to the rubber was also determined, both for the original condition and after exposure to the action of boiling water.

The specimens tested were about 22 inches in length, $1\frac{3}{8}$ inches

internal diameter, with walls ⅜-inch thick, and examination showed that the rubber penetrated the fibers of the linen so that it appeared to be of one entire mass. A number of samples were tested, and the results are tabulated fully in the original paper, together with a description of the apparatus used. The circumference of each piece was carefully measured near each end and in the middle, both before testing and afterwards, as well as during the application of the pressure, and similar measurements were made of the length.

So far as resistance to cold-water pressure is concerned, the specimens tested gave excellent results, the slight increase in diameter under 150 pounds pressure disappearing entirely when the pressure was relieved. The corresponding tests with water at 170 degrees Fahrenheit, resulted in a permanent increase in circumference of about ¼ inch, but the hose appeared otherwise unaffected. The specimens, however, failed to resist satisfactorily the test of 150 pounds steam pressure, as the circumference was enlarged nearly an inch and the length diminished 0.6 inch, while the outer covering was loosened and partly destroyed. The twisting action which takes place consequent upon prolonged internal steam pressure was shown by the fact that one specimen twisted 15 degrees when under steam pressure of 60 pounds for three hours, with a permanent twist of 8 degrees, and another specimen showed 9 degrees twist and a permanent set of 2 degrees.

The action of prolonged heat varied according to the manner of application. Rings cut from various portions and opened out, were pulled in the Rudeloff testing machine, both in the original condition and after heating. Exposure to steam heat at 350 degrees Fahrenheit for four hours made the rubber much softer, the extensibility under given load being increased fully three times and the ultimate strength diminished to less than one-fifth its original amount. Exposure to dry air at 350 degrees Fahrenheit for four hours, on the contrary, made the rubber harder and diminished the extensibility very greatly, although the ultimate strength was reduced nearly as much as with the steam.

When the material was exposed to the action of boiling water for half an hour, the adhesion of the linen layers to the rubber was not appreciably reduced.

In view of the importance of producing hose which shall satisfactorily meet the requirements of the German railways, these tests should prove of especial value not only to manufacturers of rubber goods, but also to the engineering profession generally.

METHODS OF TESTING BLOWING FANS.

A paper which was intended to call attention to certain difficulties experienced in the testing of blowers was presented by Professor R. C. Carpenter, of Cornell University, at the recent meeting of the American Society of Heating and Ventilating Engineers. The object of a test of a blowing fan, as the author stated, is, in nearly every case, the determination of the capacity of the fan either to move a given volume of air or to produce a certain pressure, or the determination of both of these qualities, the determination of the power required for moving a given quantity of air under a certain pressure, and, finally, the determination of the efficiency of the fan. From complete tests as outlined can be determined the economic value of different forms, and usually the costs of moving certain quantities of air under given conditions.

To meet these requirements it is necessary to make accurate measurements, and on this point the author stated that the most difficult to obtain with any degree of accuracy is the measurement of the volume of air. The volume and weight of air delivered by the fan is almost invariably obtained by measuring the velocity of the air, and from this computing the volume and weight. The measurements of velocity of the air are usually made with the anemometer or the Pitot tube.

The Anemometer.—The anemometer was probably first used by Woltmann or Kallsténius as early as 1820, but the author stated that a form of the anemometer designed by M. Morin, as shown by Péclet in his work on "Heating and Ventilation," and which, it is stated, was used about 1840, shows that little

improvement has been made in the instrument during the last generation.

The anemometer is a delicate instrument, and its continued use is liable to increase the friction of its working parts. For this reason, he said, it should be calibrated from time to time. The method usually prescribed for calibrating an anemometer is to fix it to a revolving arm of considerable length and swing it through still air a known number of revolutions corresponding to a certain distance of travel. The error of the instrument is determined by comparing the reading of the instrument with the distance passed through by the anemometer.

Another method of calibration is by comparing the reading of the anemometer with air moving at a known velocity. The velocity of air moving through a duct of a given cross section can be computed by measuring the amount of heat required to warm the air through a certain number of degrees. This is done by a method devised by the author, using steam for heating the air and measuring the condensation to obtain the amount of heat imparted.

The general results of tests conducted by the Prussian Mining Commission in 1884 show that the anemometer gives an exaggerated value of the air discharged by a fan, especially when standardized by rotating in still air. In computing the volume of air delivered, the error in the result would be directly proportional to the error of the anemometer, which, as shown by the tests, averages not far from 10 per cent. high. The error in work performed and in efficiency, however, would vary as the cube of velocity and, consequently, as the cube of the error in the anemometer. If the anemometer error be 10 per cent., the error in work done and in efficiency would be 33 per cent.

The velocity of air flowing through a duct of given size may also be determined by the use of large measuring tanks which are alternately filled and discharged with air in such a manner as to give accurately the volume of air flowing.

The Pitot Tube.—The Pitot tube for measuring air velocity is made by connecting a delicate manometer to a tube bent in such a manner that the opening can be made to face the current of

flowing air. By comparing the readings of a manometer connected in this manner with a manometer connected so that the mouthpiece is at right angles to the current of flowing air, a difference in readings will be noticed, which is caused by the velocity of the flowing current. The reading of the tube in excess of the static pressure is produced by the velocity of air, and a series of experiments gave as a practical result for the velocity

$$v = 70\sqrt{h}$$

in which v is the velocity of the air in feet per second and h is the head, measured in inches of water, which is counterbalanced by the force causing the velocity. The result corresponds to an air temperature of 120 degrees Fahrenheit; for air at 32 degrees the velocity obtained by the formula must be multiplied by the factor 0.92, and for air at 150 degrees, by the factor 1.05, and for temperatures of the air within the range included by different intervening factors.

By connecting one side of the manometer to a Pitot tube and the other side to a plain tube the manometer may be made to show the difference of pressure due to the velocity of the air by a single reading and without subtraction. A form of Pitot tube of this class, with a delicate reading manometer, was designed by the author.

In practice it will be found that quite accurate measurements of the velocity can be obtained for the higher manometer readings, but that a considerable percentage of error will be likely to result in obtaining the velocity from the low manometer readings, due principally to the difficulty of making accurate readings of low manometer values. The Pitot tube is, consequently, well adapted for measuring high velocities of air, and, with a sufficiently delicate manometer, it will give good results in measuring moderately low velocities. It is not, however, as well adapted for low velocities as the anemometer, nor can it be used as conveniently. It will give the velocity at a position of limited area, and hence it is possible to obtain the velocity at any given point in the cross-section of a flue, and at some distance from the manometer.

Pressure Measurement.—The difference in pressure produced by a blowing fan is usually very small compared with the total barometric pressure, and is ordinarily measured by some delicate gage. The simplest apparatus, and the one most commonly used, is a U-shaped tube filled with some liquid, such as water. One side of this tube is put in connection with the vessel subjected to the pressure to be measured; the other is connected with the atmosphere, or, as explained in the discussion on the Pitot tube, in such a manner that the difference of any two pressures may read directly.

The delicacy of the instrument will depend upon the weight of the liquid used; the heavier the liquid, the less delicate is the instrument. For the measurement of air pressures water is ordinarily employed, and the results obtained are expressed directly in inches of water or are reduced to ounces or pounds per square inch. By locating the U-shaped manometer in such a position that the eye can sight over the under surface of the liquid in the tube, a very delicate reading may be determined by aid of the total reflection of light as seen from the meniscus at the top of column of liquid. An elevation considerably less than one-hundredth of an inch can thus be determined with accuracy. By arranging a point back of the last tube and one in front, and noting the position of the bottom of the meniscus, very delicate changes can be read.

The Work of the Fan.—The work performed by the fan is made up of the resistance due to moving and compressing a definite amount of air. It can all be considered as equivalent to moving a given weight of air through a height or head which is equivalent to the sum of the velocity and pressure heads expressed in feet of air at the density corresponding to the air after being compressed.

In testing a fan it will be found that the pressure head, as measured from the manometer, will be smallest, as a usual thing, when the velocity head, as measured from a Pitot tube, is highest, and *vice versa.* Hence, it is essential to measure these two quantities at the same point.

Efficiency.—The efficiency of a fan is to be found by dividing the work supplied by that usefully applied in moving the air and computed as explained.

Notes Regarding Testing.—It will be found in the actual operation of testing fans that the air delivered moves in irregular currents, and, consequently, in order to obtain average results, readings must be taken in all portions of a given cross-section. In order to obtain the average readings the cross-section should be subdivided into a number of small sections of equal area, and the velocity in each one of these smaller subdivisions should be obtained by the method described.

In case the subdivisions are not of equal area, an allowance should be made in determining the average for those subdivisions which are larger by multiplying the readings by factors giving the relative proportion of area. As a rule the pressure and velocity readings of the fan should only be taken after the air has traveled some distance in order that the inequalities spoken of may be lessened as much as possible. The use of baffle plates to equalize the velocities and pressures is likely to add considerable friction head to the fan, and they are not recommended.

Many of the tests which have been recorded of fans show an abnormal and sometimes an impossible efficiency. This is usually due to errors in the anemometer used.

There are certain losses which necessarily take place in the fan when constructed in the most perfect form, which are due to the striking of the particles of air against the vanes, to adverse air currents at the point of discharge from the vanes, and to friction against the casing. It is considered by some authorities that the unavoidable losses will reach from 25 to 33 per cent. of the power supplied the fan, and hence the limit of possible fan construction will result in an efficiency of from 66 to 75 per cent. The efficiency of a fan varies with the pressure against which it works, the highest efficiency being usually found in experiments of the author when the fan is working under a back pressure of approximately one ounce. Working under the condition of highest efficiency, the fan discharges the greatest

weights of air per horsepower, but not necessarily the greatest volume, unless the volume be measured at asmospheric pressure.

It will also be found that the form of the fan blades has considerable effect on the results. In experiments of the author, which were described in full in the "Engineering Record" of March 4, 1899, with different forms of blades at a given speed, the highest pressures have resulted when the fan blades were bent forward and the highest efficiency when the fan blades were bent backward.

The general results of his experiments, the author stated, would indicate that a fan efficiency of from 40 to 50 per cent. is as high as can be expected with the best construction working under usual conditions.—"The Engineering Record."

SYSTEM OF ELECTRIC DRIVING IN SHOPS.

The present indications are that during the next few years all new shops and many remodeled old ones will have some, if not all, of the machines driven by electric power. Long lines of shafting often require from 60 to 75 per cent. of the total power to overcome friction, and it is safe to count upon enough saving in power by the introduction of electric motors to furnish light for the same shops. The question of fuel economy, however, is not the most important one, because with wasteful systems the cost of power is usually about 2 per cent. of the cost of labor. The important question is to get the most out of the plant. The Baldwin Locomotive Works several years ago expended about $65,000 in electrical machines, and the cost is saved every year in the saving of labor. The Chicago, Milwaukee & St. Paul Railway installed an electric motor to operate a turn-table. The cost was $550, and it saves $1,600 per year in wages.

Electric motors are accepted as offering valuable means for increased shop output; they are reliable, efficient and worthy of confidence; they are ready to respond instantly to a demand greatly in excess of their rated capacity, and they have the further advantage of accurate and easy adjustment of speed. It is not easy, however, to learn the best method of obtaining these ad-

vantages in practice. Each individual plant has its characteristics to be considered, and one of the limiting factors in the adoption of a plant of electric driving is the relative cost and efficiency of large and small motors. Seventy-five dollars per horsepower for one-horsepower motors and twenty dollars per horsepower for fifty-horsepower motors may be taken as an approximately correct proportion.

It is desirable to use as few different sizes of motors as possible, because of the repairs. These considerations lead to the comparison of four systems of motor arrangement:

1. Individual motors.
2. The group system.
3. Comparatively long lines of shafting, each driven by its motor.
4. A combination of the individual and group systems.

Individual Motors.—Where the tools are relatively large this plan reduces the losses of transmission to a minimum, and it also permits of any desired use of cranes and machinery for handling parts and finished work to and from the machines. It avoids all the troubles caused by belts, but the cost is high, and the motors will seldom be of greater capacity than 5 horsepower. The power of the motor must, of course, be sufficient for the greatest load ever put on the machine, and, for a large part of the time, much less power is required, which means rather inefficient operation of the motors. This plan also requires a large number of different sizes of motors, for which extra repair parts must be kept, and with small motors the repairs are much greater in amount than with larger ones. This system, however, uses no power except when the machines are running, which is not true of any other system.

There is no system which permits of getting so much out of the machines as that of individual motors, and in some cases this will outweigh all other considerations. With a direct-connected motor it is possible to obtain more perfect speed control than can be had in any other way. The full capacity of the tool is always available at a movement of the hand, and the machine may be started, stopped or reversed by the attendant without

changing his position. Belt shifting is not difficult, but it is one of the little things that men will not do unless it is necessary, and a little hand switch to control the speed will be used when a belt would not be shifted.

Most tools are limited in capacity by the system of driving with which they were originally fitted, and the usual range of speeds is very small. This is the only system which offers this very desirable speed and power control for each machine, and it counts powerfully in the output of a shop where it can be used.

The Group System.—This plan recommends itself where the individual machines are not large enough for independent motors and where improved transmission without too large a capital outlay is sought. Shops and factories with no large tools, and with large numbers of small-powered machines, must necessarily come under this system. It does not do away with shafting, but it permits of cutting the shafting into convenient lengths, and avoids what is probably the greatest difficulty with shafting, the friction of long lengths on account of their liability of getting out of line. The motor driving a group of machines does not need to have a capacity equal to the sum of the maximum possible demands of all of the machines, because it is safe to count upon some of them as being idle or requiring only a small amount of power. The electrical installation of the Baldwin Locomotive Works has the proportion of 1,300 horsepower in the generators to 3,500 in the motors, and it seems to be sufficient, as the average horsepower at the switchboard is but 1,000.

The groups may be arranged with a view of running certain of them overtime in order to keep up with the rest of the plant, and all of the machines required for certain overtime work would be put into that group. This system renders the selection of motors comparatively easy, and has the advantage of requiring the minimum number of different sizes; two sizes, 15 and 25-horsepower motors will suffice for many large shops. The groups may be arranged to have a surplus of power in each at the start in order to provide for expansion. If the load eventually becomes too great for the smaller size, one of the larger ones can be substituted.

Motors on Long Line Shafts.—While a number of cases of this arrangement are in successful use, the objection to it is that there is little diminution in the belting, and, in fact, no advantage over the usual steam drive, except that the steam plant may be concentrated in one place for several buildings or departments. It is a great advance over the distribution of steam engines all over a plant, but it does not bring out the best possibilities of distribution of power by electric motors. Two motors may run a shop or department, one being at the center of each side of the building and connected each way by clutches to the shafting. This permits of running one-quarter of the shop alone, but it involves running long shafting and many idle belts in order to reach a few machines for overtime work. The cost of the motors is less, but their efficiency is not sure to be higher, because of the lack of flexibility of the system. This plan does not accommodate good crane service.

Combined Individual and Group System.—By running the heaviest and largest machines by direct-connected motors, stopping at those requiring less than about 5 horsepower, and grouping the smaller machines to motors of from 5 horsepower up, a very satisfactory system may be devised. This is the one followed at the Baldwin Locomotive Works and in a number of large establishments. It is flexible enough for adaptation to all except extraordinary conditions.

Determination of Power Required.—The indicator affords the readiest and most reliable information concerning the amount of power required. In applying motors to an old shop the full load of the shop may be ascertained at the engine by indicating, and the sizes of the sections or groups may be determined by cutting off portions of the shop successively at the shaft couplings. This will probably be necessary for each individual case, particularly where the groups involve much belting and shafting. For electric drives in new shops there are few reliable data available to the reader, and the best plan is to entrust such a problem to the information and judgment of a reliable electric machinery concern. We expect to have more to say on the determination of the power required for installing motors in old shops in a future issue.—"American Engineer and Railroad Journal."

THE RECONSTRUCTION OF A DRY DOCK.

About six months ago an article was printed in these pages (the "Engineering Record") describing the failure of Dry Dock No. 2 in the Brooklyn navy yard. This was a timber structure built about nine years before, and had given signs of weakness for some time. During the Spanish war it was impracticable to put it out of service for repairs, but Congress appropriated $300,000 for reconstruction when an opportunity offered. Ever since the dock was put in service it admitted water in sufficient volume to cause some undermining of the inclined timber sides. The cavities thus formed were filled whenever they were detected, but it was impossible to ram the filling as thoroughly as was done during the original construction. On the evening of July 13, 1899, there was a heavy rainfall which could not be carried away entirely by the sewers of the navy yard. Some of the water evidently entered the cavities behind the timbers and filled them so as to bring a heavy hydrostatic pressure against the sides of the dock. This forced the structure inward, breaking the timber. At the abutment angle the dislocation extended for about fifty feet longitudinally and down to within a few feet of the floor of the dock. An examination showed that the timber was badly decayed. The altar system in the body of the dock was distorted throughout nearly its entire length, the cross caps and piling were found to be decayed, and the complete reconstruction of the dock was made imperative.

The original dimensions of the dock were 500 feet length, 130 feet width on top and 32 feet depth. The timber altars were carried by inclined sills, supported on vertical piles and braced against rows of braced piles by long inclined struts. The type of construction was what is known as the Simpson dock. The earth at the site consists of 10 feet of loose fill at the top, underlaid by clay, peat, sand, silt and similar material. The ground water level is 10 or 12 feet below the surface and renders the earth a sort of mica sand when deep excavations are made in it. A recent excavation in the vicinity caused a large coal pile 500 feet away to sink about 5 feet during the progress of the digging.

The reconstruction is very thorough, and when it is completed the dock will be practically a masonry structure, 72 feet wide on the bottom, 112 feet wide on the top and about 500 feet long. It will be noticed that the top width will be decreased and the bottom width increased. This has been accomplished by giving the masonry side walls a much steeper slope than those of the old timber dock.

The dock was closed with the old caisson, well braced inside so as to form a cofferdam. Abutments for a new caisson just inside the old one will be built as soon as possible, and then the new caisson itself will be constructed and put in place. The new side walls have a vertical exterior face, a bottom width of 24 feet and a top width of 4 feet. They rest on close-driven piles, and are formed of Portland cement concrete, mixed 1, 2 and 5, using unscreened crushed granite. The lowest seven altars are faced with mortar of 1 to 1 Portland cement, while the remaining altars are to be of cut granite.

The reconstruction at the sea end of the side walls was begun by removing the old slope timbers and excavating a trench about 14 feet deep from the surface of the ground around the outer faces of the new walls. In this trench temporary pile bents were driven to carry pile-driving machines with which a continuous wall of heavy permanent sheet piling was driven. The inner face of this piling is coincident with the outer vertical face of the new concrete walls. The earth below the lower portion of the old altar system is then removed by pick and shovel and hoisted from the pit in iron buckets. When the excavation reaches the level of the bottom of the old floor, the pit, which is about 35 feet wide, is filled with 50-foot yellow-pine piles on 2-foot centers. Although these are not driven to refusal, they become fixed so firmly that it is impracticable to withdraw them with a force of 60 tons. The excavation is then continued to a depth of 6 feet below the floor level, the pile tops are cut off about 6 inches above the bottom of the concrete, when it shall have been placed.

The sheet-pile work is very close and accurate, and when one surface is exposed by excavation an almost vertical straight wall

is revealed, through which scarcely any water penetrates. The sheet piles are 12 by 12-inch yellow-pine timbers from 46 to 54 feet long, planed on all sides and cut with grooves 2 inches square on two opposite sides. Cast-steel shoes are bolted to their lower ends and heavy steel bands are placed around their tops. The splines used in the grooves are 2 by 4-inch white-pine pieces, and are spiked in one groove of each pile before driving. The piles are greased and driven between two double rows of 8 by 12-inch horizontal waling pieces, to which they are bolted every 2 feet. The upper set of wales is 12 feet below the ground, and the second set 7 feet lower. Each sheet pile is held tightly against that last driven by oak wedges forced between it and a cross timber bolted on top of each pair of waling pieces a little in advance of the pile. There is a tendency for the wedges to work loose, and men are stationed on each line of wales to keep them tight. The piles penetrate more than 20 feet below the dock floor. After the side walls are finished, the concrete will be extended so as to enclose the top of the sheeting and form a bed for part of the 18-foot track on which a 40-ton traveling crane will run.

The excavated material is removed in 3-yard side-dump cars, running on tracks along the sides of the dock to a dump, which is a pile trestle so built that a scow 30 feet wide can be run below it. At present it takes about two days to load a 500-yard scow, which is dumped in deep water off Sandy Hook.

The water which enters the pit is removed by the regular dock pumps. The old suction pipe will be replaced by a much larger one, 45 inches in diameter and bedded in concrete. The water collecting in the local depressions is forced to the main sump by a 6-inch centrifugal pump mounted on the same bed as a dynamo, the runner of the pump and the armature of the dynamo being on the same shaft. This arrangement has been found very convenient. Steam syphons have also been occasionally used for the same purpose.

The materials for the concrete are measured on a platform on top of the bank. They are then shoveled into the top of a gravity mixer, which discharges them into the mold where

they are to be rammed. The concrete is placed in 9-inch layers in heavy timber forms, and is carefully joined to the old concrete bottom, which is the only part of the timber dock to be left undisturbed. The mixer is moved along as the wall is advanced. The work is carried on in sections of full width, 40 to 50 feet in length, and a considerable length of footing is laid before any part of the wall is completed to the full height. About 20 men in all are required on the concrete work, with each gravity mixer, on one wall, and as much as 70 yards of material have been placed by one of these gangs in a day of eight hours. Particular care is taken not to tear out the old work faster than the new can be built.

The total quantities involved in the reconstruction are 45,000 yards of earth excavation, 28,000 yards of concrete and 1,000 M. feet of timber. About 150 men are now employed, and the plant includes two 40-ton locomotive derricks, five 3,000-pound pile drivers, two locomotives, two stiff-legged boom derricks, and minor accessories. The work is being done under the general supervision of Admiral M. T. Endicott, Chief of the Bureau of Yards and Docks, Captain P. C. Asserson, of the same bureau, being in direct charge. The work is done by day labor on account of its difficulty and the impossibility of specifying all the conditions which a contractor would have to meet.

CALCULATING MACHINES.

Calculating machines have been in use for so long, and are used at the present time by so many people, that it would be natural to suppose that everybody would have some sort of acquaintance with them and some idea of the principles on which they work. Personal experience, however, shows that a calculating machine is nearly always regarded as a novelty, and usually as something exceptionally wonderful. When people see an oblong box containing sundry cogwheels, handles and brass plates, they look at it with curiosity and inquire what it is, and when the instrument is explained to them an admirable opportunity is afforded of testing the veracity of the observer. If he, and still

more conspicuously, if she, professes to understand it, it may be doubted whether the familiar assertion associated with George Washington is applicable. If it is pronounced very wonderful, but quite incomprehensible, the visitor is probably telling the truth, and yet practically all calculating machines are really very simple. With the ancient abacus, which consists of balls sliding upon parallel rods, most people are familiar, and the Chinese shwan-pan, which is but a variation of the abacus, is well known to many travelers, who are invariably struck by the facility with which calculations are made by its aid.

The first recorded attempt at an arithmetical instrument in Great Britain was made by Napier, the inventor of logarithms, early in the seventeenth century. It consisted simply of a movable multiplication table, somewhat flippantly called 'Napier's bones,' in spite of the fact that the inventor christened his system rhabdology. There is much that is good about these 'bones,' but as a calculating instrument it will not compare for a moment with logarithms, for which we are largely indebted to Napier.

The first real calculating machine was invented by the philosopher Paschal, about 1650. He was then a lad of nineteen, helping his father in work which required much calculation, and he contrived a series of wheels connected with one another, with the ten numbers 9 to 0 engraved on each. Addition and subtration were performed by turning the appropriate wheels by hand, the carrying over being mechanically provided for. The machine was of very little use.

About twenty years later Leibnitz, the mathematician, invented a machine which is believed to have been of an extremely complicated nature, but no clear description of it is to be found. An interesting 'calculating table' was contrived by Dr. Saunderson, a Cambridge professor of mathematics, who was entirely blind, and designed the instrument for his own use. It seems to have been a board about a foot square, divided into many little squares, and perforated with small holes, in which pins could be stuck indicating various numbers. It is said that 'he could place and displace his pins with incredible nimbleness and facility, much to the pleasure and surprise of all the

beholders. He could even break off in the middle of a calculation and resume it when he pleased, and could presently know the condition of it by only drawing his fingers gently over the table.'

Whenever calculating machines are mentioned people invariably think of Charles Babbage, who undoubtedly designed by far the most complete machine that has ever been invented. To describe it in full, and tell the story of its manufacture, so far as it went, would take several volumes, since even a large quarto volume, devoted entirely to the subject, leaves out a great deal about it that it would be interesting to know. Babbage's machine was designed to calculate elaborate tables and automatically set them up in type, or else supply a mold in which stereotyped plates of the tables could be cast. After many experiments, he constructed his first difference engine, as he called it, for the reason that he employed the method of differences as a general principle on which to base the calculations. As soon as the first machine was completed, Babbage received instructions from the British Government to construct another and more comprehensive one at their expense. Six years after this order was given the Treasury appointed a very strong committee to examine and report upon the portion of the machinery then executed and the design for the whole engine. The result was a very strong expression of opinion in favor of the machine, but the expense was enormous. The Government finally declined further supplies, and in 1833 the construction of the engine was relinquished. The second difference engine was a huge instrument of marvelous power, and an illustration that Babbage himself uses as a kind of illustration of a miracle shows one feature of its performances in an interesting way. He said that his machine would go on for years working by the same formula. It could then change without human intervention to another formula for a single calculation, and subsequently resume working by the original formula.

But, great as were the powers of this second difference engine, Babbage had conceived an even more elaborate machine, which he called the analytical engine, which would completely

supersede the difference engine, on which, in its incompleted state, the Government had already spent £17,000. It is not wonderful that the Chancellor of the Exchequer declined to supply any more funds under these circumstances.

Two practically useful machines were, however, constructed on Babbage's principles, one of which, made by Scheutz, a Swede, was completed at a total expense of £560, which was provided by the diet of Stockholm. This machine was about the size of a small square piano, and would calculate and stereotype without chance of error two and a half pages of figures in the same time that a skillful compositor would take to merely set up the type for a single page. The machine was purchased for £1,000 and presented to the Dudley Observatory at Albany, N. Y. A second Scheutz machine was made for the English Government for £1,200, and was used for, among other work, portions of the English Life Table No. 3. The machine consists of over 4,000 pieces, and weighs about half a ton.

Since Babbage's day many small calculating machines of various kinds have been invented, and when the present writer searched the records of the Patent Office to see if an invention of his own had been anticipated, he was surprised to find that an enormous number of patents for such instruments had been taken out. The specifications proved very interesting reading, and exhibited for the most part a remarkable amount of ingenuity, which, sad to relate, must have involved the inventors in a very large expenditure, from which they received no return; but this is the ordinary fate inventors meet with.

There are practically only five of these machines that are worth mentioning. One of these, invented during the past few years, is Burroughes' registering accountant, which performs addition by striking keys like those of a typewriter, and at the same time types on a strip of paper, the amounts that have been added. This machine seems to be mechanically successful, but, so far as the writer is aware, it is not now commercially obtainable. It is somewhat heavy and cumbersome, requiring ten keys for every column in a row that it is desired to add. An obvious improvement would be to put the calculating mechanism on a

carriage like that of a typewriter, and use ten keys in all, instead of the seventy or eighty keys that in its present form the machine requires.

Another moderately practical machine is an American invention called the comptometer. This also is actuated by keys like those of a typewriter, and by means of it it is simple to add, feasible to subtract, and within the bounds of possibility to multiply or divide; for the latter purposes it is altogether inferior to Tate's arithmometer. A machine that has much that is pleasing about its designs is the Brunsviga, but its workmanship is not sufficiently good to stand much wear and tear. The writer obtained one about five years ago and has long since worn it out.

The only really satisfactory machine for multiplication and division was invented by Thomas de Colmar about 1850. This was subsequently improved in design and workmanship, without being altered in principle, by an Englishman named Tate, and years of hard work at one of these machines has led to the keenest appreciation of its powers. It never makes a mistake, it practically never gets out of order, it performs multiplication and subtraction with ridiculous ease, it makes the abstraction of the square root quite a fascinating operation, and for many purposes can be used by an unskilled operator with entire confidence that the calculations will be correctly performed. The arithmometer is largely used by life assurance companies, and anyone whose work consists to any great extent of calculations can scarcely be too thankful that it was invented. It is contained in a box about 2 feet long and 6 inches high, and is the machine referred to at the beginning of this article.—"Pall Mall Gazette."

In commenting on the above the "American Machinist" says that it is probably not generally known that Geo. B. Grant, of gear-wheel fame, invented a calculating machine of great ingenuity, and having many excellent features, especially as a multiplier. This operation it performs with great facility and absolute accuracy. It also adds, subtracts and divides. In this machine there are a number of small gear wheels with numbers on them which are revolved by movable racks, each rack being set by means of pins to figures indicating the amounts to be handled.

After that a revolution of a crank adds the amount, or continued turning of it multiplies the amount, and the device for "carrying" from one wheel to another is particularly ingenious.

STRENGTH OF STEEL BALLS.

Reliable data of the actual breaking strength of steel balls not being obtainable, a number of tests were made at the Rose Polytechnic Institute preliminary to the design of some ball bearings for experimental purposes, and the following is an abstract of these tests, from a paper by J. F. W. Harris, read at the last meeting of the American Society of Mechanical Engineers.

The balls were obtained in every case directly from the manufacturers, who are designated in the tests by the letters A to F.

The first experiments in crushing were made with the ball between two flat plates of a high-grade tool steel, which had been hardened in brine. These proved unsatisfactory, the ball imbedding itself to a considerable depth. After trying several high-grade steel plates of different brands with no better success, a method was adopted, in which the hardness of the balls themselves was used to obtain a mutually unyielding surface. This apparatus consisted of a short steel cylinder bored axially to two diameters, the shoulder formed by the junction of the two different bores being made perfectly flat, and located nearly midway of the height of the cylinder. Resting upon this shoulder is a thin steel plate, having a hole bored concentric with the cylinder, with a diameter $\frac{1}{100}$ inch larger than that of the ball being tested. This plate serves as a guide for the central ball, retaining it in the axial line. Fitting snugly into the bottom of the cylinder is a hardened steel plug, having a conical recess in the center of its upper surface to retain the bottom ball. In the upper end of the cylinder is a similar plug, fitting loosely, to allow its vertical movement under pressure without friction. After adjusting a ball on the bottom plug, the test ball in the hole in the central plate, and another ball on top of that fitting in recess of the top plunger plug, this apparatus was

placed between the heads of a 100,000-pound Riehle testing machine.

While making these tests of ball on ball the search was continued for a steel which would harden sufficiently to be used as ball races without injurious grooving under ordinary pressures. Several grades of various brands of tool steel, hardened in brine, were tried, their comparative hardness being ascertained by measuring the depression made by a $\frac{1}{4}$-inch ball under a load of 4,000 pounds. These tests resulted in the selection of a steel known to the trade as crucible tool or file steel, and a special steel made by the Carpenter Steel Company, used by them in the manufacture of projectiles. All balls up to and including $\frac{1}{2}$ inch in diameter were tested between two plates of Carpenter Steel of $1\frac{3}{16}$ inch diameter and 1 inch in length. The indentations made were almost imperceptible, and were removed by grinding after each series of tests. The larger balls were tested between plates of crucible tool steel 2 inches square and $\frac{7}{8}$ inch thick, on which but slight indentations were produced.

The results obtained by both methods of testing are shown in the accompanying table of "Breaking Loads," in which the various tests are arranged in order of magnitude for better comparisons, the numbers in the second column not having reference to order of test. The wide variations as shown therein arise principally from the difference in temper, which varied from brittle hard to that which could be filed with a Stubs smooth file. The softest balls required the greatest pressure, and flattened until they finally split. The larger number of medium temper split in two pieces, the hardest broke up into a number of pieces.

In testing ball on ball, the center ball was broken in about 80 per cent. of the cases, the break occurring by the formation and forcing of a nearly conical wedge into the ball, the base of the cone being approximately circular. The angle of this wedge was about 60 degrees. When crushing between flat plates this wedge was formed in but very few cases, the balls generally breaking up into a number of pieces, the angle of the wedge in this case being about 75 degrees. Of the defects found in the

balls other than those of temper, there are four cases of hollow center.

BREAKING LOADS.

Diameter of ball.	Ball on ball.					
	A.	B.	C.	D.	E.	F.
$\frac{1}{8}$ inch, average	1,523	993	1,673	1,210	1,046	1,232
$\frac{3}{16}$ inch, average	2,713	2,202	2,526	1,330	2,440	2,783
$\frac{1}{4}$ inch, average	4,063	4,162	4,196	3,313	4,656	4,526
$\frac{5}{16}$ inch, average	6,110	5,960	5,600	5,683	7,635	7,156
$\frac{3}{8}$ inch, average	7,843	6,200	8,703	11,200	6,933	13,310
$\frac{1}{2}$ inch, average	20,966	.....	17,900	.....	11,273	.....
$\frac{5}{8}$ inch, average	23,516	.....	.....	.....	13,646	.....
1 inch, average	59,033	.....	.....	.....	.....	.....
	Between flat plates.					
	A_1.	B_1.	C_1.	D_1.	E_1.	F_1.
$\frac{1}{8}$ inch, average	2,450	1,850	2,100	1,313	1,483	1,690
$\frac{3}{16}$ inch, average	3,836	3,837	2,966	2,225	4,400	3,887
$\frac{1}{4}$ inch, average	8,666	5,687	5,566	6,033	6,337	7,150
$\frac{5}{16}$ inch, average	8,993	6,887	10,833	7,733	9,275	10,200
$\frac{3}{8}$ inch, average	14,940	14,042	10,583	10,500	12,800	13,337
$\frac{1}{2}$ inch, average	41,770	.....	20,883	14,833	12,966	.....
$\frac{5}{8}$ inch, average	38,866	.....	.....	.....	21,125	.....
1 inch, average	90,650	.....	.....	.....	.....	.....

Some experiments to determine the effect of the difference of area in contact on the breaking strength are being made, a few of which are given in the following table:

BREAKING LOADS.

	1.	2.	3.	4.	5.	6.	7.	8.
B_2, upper ball, $\frac{5}{16}$-inch	6,700	.....	.....	7,000	.....	.....	.....	.....
B_2, center ball, $\frac{3}{8}$-inch	.....	5,400	6,300	.....	.....	6,000	.....	5,500
B_2, lower ball, $\frac{5}{16}$-inch	.....	.....	.....	.....	4,000	.....	5,650	.....

	9.	10.	11.	12.
B_2, upper ball, $\frac{1}{4}$-inch	6,400	4,950	4,000	.....
B_2, center ball, $\frac{3}{8}$-inch	.....	.....	.....	.....
B_2, lower ball, $\frac{1}{4}$-inch	.....	.....	.....	5,780

—"The Iron Age."

SCARCITY OF SAILORS.

At the beginning of 1899 the total number of men in the service of the German navy was 23,400, including the officers

and engineers and a few surgeons, gunsmiths and paymasters. From Berlin it is reported that with the rapid growth and proposed further increase of the German navy there has been an increasing scarcity of trained young sailors. A few years ago Germany furnished a large part of the crews of English vessels, but to-day the crews of Germany's vessels are partly composed of foreigners. With the doubling of the German navy, as contemplated, this difficulty will increase, and steps are being taken to meet it. At Bremen the North German Lloyd Company is organizing a cadet school to train young men for the company's service. The demand for additional sailors in Germany is not limited to the government service, however, for the two chief German lines of ocean steamships have, collectively, crews of 4,800 sailors, exclusive of the lines connecting German ports with other countries in the enormous and constantly increasing German shipping trade. Heretofore a country supplying many other countries with sailors has been Sweden, but the decrease of foreign commerce of that country and the demand for Swedish sailors for Russian ships has diminished the number of such sailors available. Moreover, Germany is only one of the countries in which there has recently been an extensive development of the naval armament and an enlarged demand in consequence for sailors.

At the beginning of the year 1898 the total number of men in the naval service of Great Britain was 100,000, of whom 70,000 were officially described as "officers and seamen" and 20,000 were "marines." Since then a further increase of transport service of the English Government to South Africa has made necessary the increase in the number of sailors. There has been a very considerable increase of sailors in consequence of the enlargement and improvement of the United States navy, and the demand for them in the merchant marine of the country has been increasing correspondingly. The American Line employs 2,500 sailors, and the enlargement of ocean travel this next summer to and from the Paris Exposition will make further demands upon the service of sailors in all transatlantic lines. Two European countries which are adding considerable to their naval

equipment are France and Russia, and the increased Dutch commerce makes necessary the employment of a considerable number of Dutch seamen under the home flag. Dutch sailors have an excellent repute and number in all more than 40,000, of whom less than 10,000 are in the naval service of the country.

There are, it is computed, a quarter of a million sailors connected with the navies of the various countries and 750,000 sailors employed in commercial navigation. England, the United States and Sweden ranking in this order in that regard. Germany, France, Italy and Holland are large commercial nations, too, and it has been observed generally that German sailors come from the northern provinces of the country, particularly the Baltic and the North Sea, while French sailors almost uniformly are drawn from the two provinces of Brittany and Normandy. The threatened dearth of available sailors, which some German companies are seeking to provide against by the establishment of a cadet school, affects other countries as well, and unless all indications are at fault the demand for sailors next summer will be more extensive than ever before in the world's history.—"American Shipbuilder."

INCIDENTAL USES OF SERIES FIELD WINDINGS OF COMPOUND DYNAMOS.

Mr. Wm. A. Anthony, in questioning an editorial in the "Electrical World and Engineer," of November 25th, upon "Incidental Uses of Series Field Windings of Compound Dynamos," writes as follows: "The statement is made that 'the series field of the fresh machine should, of course, be thrown in parallel with the other series fields * * * before the voltage of the fresh machine is adjusted to equality with the others.' Let us see.

"Assume two equal machines, *A* and *B*, *A* running on full load and *B* to be coupled with it. The series field are placed in parallel. This takes half the current from the series field of *A*, and reduces by half the effect of *A's* series field to maintain its e. m. f.; consequently its e. m. f., and the voltage on the whole system, drops by ten volts or more, constituting of itself a rather serious disturbance of the regulation. Now, if I understand cor-

rectly, the voltage of *B* is adjusted to equality with that of the system, with a half-load current in its series field, but its armature producing no current. Under such a condition how can *B* assume any part of the load? It can only assume its share through an adjustment of its shunt field, which raises its voltage and that of the whole system to its original value.

"How will it be if the e. m. f. of *B* is adjusted before its series field is paralleled with *A's*? *B's* voltage is made equal to that on the system. Then its circuit and equalizing switches are thrown in together. The current quickly divides between the two series fields; the magnetism of *B's* field increases and that of *A's* field decreases, causing *A's* armature to give up and *B's* armature to assume half the current, and this without any change in the voltage at the bus bars. If the machines are evenly compounded, which all machines to be used in multiple should be, no further adjustment should be needed.

"If the machines are over-compounded, say five volts, and *B* is adjusted to equality with the system, while its equalizer switch is open, the effect of closing the circuit and equalizer switches at the same time will be that the e. m. f. of *B* rises about two and a half volts, while that of *A* falls by the same amount. This does not materially alter the voltage of the system. Its only effect is to cause *B* to take more than its share of the load. The loads may then be equalized by an adjustment of both field rheostats without changing the voltage on the system.

"All this is in accord with my experience in coupling compound-wound dynamos for the last ten years.

"The statement is made that when the fresh machine is adjusted after its series field is parallel with the others, there is no jump in its voltage on coupling it to the circuit. Very true, but I have never found any jump in voltage when the e. m. f. of the fresh machine is adjusted with its equalizer switch open. There may be a jump in the e. m. f. of the fresh machine, but that jump is just what is necessary to enable it to maintain a constant *voltage* at its terminals when its armature assumes its share of the current."

To this the editor replies: Professor Wm. A. Anthony takes

the stand that the throwing of an unloaded compound-wound machine in parallel with another under load does not alter the voltage of the latter. The argument is, of course, true for machines compounded for constant potential, but is not true for machines which are overcompounded. With a machine wound, let us say, for a rise of voltage of 10 per cent. at full load, throwing off half its load of course reduces the voltage about 5 per cent. Mr. Anthony's letter is an argument for the paralleling of machines in the old way by means of one triple-pole switch as against the more modern method of paralleling by means of one double-pole switch in the equalizer and positive leads, followed by the closing of a single-pole switch in the negative lead.

The difficulty involved in paralleling highly overcompounded machines of modern type with close speed regulation, slow armature reaction, stiff fields and small internal resistances, may be illustrated by the following supposititious case: Assume a railway power plant with one such machine wound for a 10 per cent. rise of voltage at full load, carrying its full rated load of, let us say, 1,000 ampères, and delivering 550 volts. As the load rises it becomes necessary to throw in another machine in parallel with it. If this operation is carried out on the plan indicated by Mr. Anthony, the fresh machine would be excited by its shunt field up to 550 volts. On closing the triple-pole main switch of the fresh machine, its series field will be thrown in parallel with that of the machine already loaded, and will begin to take over some of the current. Assuming that the series fields of the two machines have the same resistance and the equalizer and positive mains are of sufficiently low resistance to place them in a perfect parallel connection with each other, the voltage of the fresh machine will rise to about 575 volts, and the voltage of the other machine will fall to about 525. This is neglecting the bend of the magnetization curve, which will reduce this difference slightly. The result will be a complete transfer of the load from one machine to the other, which, however, as a rule, is gradual owing to the slow transference of the current from one series field to the other, and in turn due to the high ratio of self-induction of the resistances of these circuits. On account or this slow trans-

ference the attendant can, as a rule, check it by manipulating the shunt field rheostats, but in case of faulty equalizers, poorly adjusted governors, or other troubles, the manipulation of the machines proves very difficult.

If the attempt is made to adjust the voltage of the machine to a lower value than that of the busbars before throwing it in, the fresh machine when thrown in by means of the triple-pole switch, acts heavily as a motor until its series field gets part of the outgoing current. If there is any fault in the equalizer, this motor current will back up through the series coils of the fresh machine, and still further weaken its field and cause disastrous consequences. In case the series field of the fresh machine is thrown in before its armature circuit is closed, the voltage of the other machine will fall off materially unless its field rheostat is given a twist to build up the shunt field as the series field builds down, which may readily be done owing to the slow transference mentioned above. The voltage of the two machines may then be adjusted to equality and the negative switch of the fresh machine closed without the transference of a single ampère. The load may then be changed off from one machine to the other by manipulating the two field rheostats.

THE NET COST OF WARSHIPS IN ENGLAND AND FRANCE.

In a note of the French Navy Department it is stated that the relative cost of construction of warships in France and England have changed very much in the last few years, and that unfavorably as regards France. The following table gives information as to the cost of some French and English ironclads:

.....	Name.	Displacement.	Price.	Price per ton.
1887–1890	*Trafalgar*, English	11,940	$3,715,320	$310
"	*Camperdown*, English	10,606	3,394,070	320
"	*Formidable*, French	11,910	3,286,153	276
"	*Hoche*, French	10,500	3,463,072	330
1891–1893	*Centurion*, English	10,500	2,605,300	248
"	*Repulse*, English	14,150	3,779,560	267
"	*Empress of India*, English	14,150	3,839,020	271
"	*Brennus*, French	10,943	4,263,400	388
"	*Charles Martel*, French	11,882	4,811,600	407

It is seen that the net cost of the ironclads was originally about equal, but that they have changed nearly 30 per cent. to the disadvantage of France.

For cruisers the proportions are similar, or even worse for France, as is shown in—

.....	Name.	Displacement.	Price.	Price per ton.
1888–1892	*Blake*, English	9,000	$1,969,440	$219
"	*Bonaventure*, English	4,360	1,028,840	236
"	*Cecille*, French	5,660	1,468,000	259
"	*Alger*, French	4,330	1,424,652	329
1892–1896	*Gibraltar*, English	7,700	1,496,880	194
"	*D'Entrecasteaux*, French	8,100	2,854,480	352

These notable differences in cost are, according to the writer, not due only perhaps to a more careful execution of the work on the ships in France, but there are other reasons, of which some are named as follows:

1. The English ships are built more frequently after one type; ten ironclads of the years 1886 to 1891 are built according to five types; eight new ironclads are entirely alike.

2. They have been launched quickly one after the other.

3. The construction is directed from one central Bureau in London.

4. Economy in materials is obtained by the fact that boilers, engines and auxiliaries, etc., are built by firms specially equipped for such work.

5. The prices of materials in England have fallen while those of France have risen, as shown in

.....	Name.	Total price of materials.	Price per ton.
1885–1897	*Trafalgar*, English	$2,316,680	$194
"	*Camperdown*, English	1,771,570	167
"	*Formidable*, French	1,868,855	147
"	*Hoche*, French	1,948,342	185
1891–1893	*Centurion*, English	1,245,220	118
"	*Repulse*, English	2,261,080	159
"	*Brennus*, French	2,739,600	249
"	*Charles Martel*, French	3,260,000	274

Therefore, the prices of materials in France are twice as much as those in England (1895) outside of the armor plates, which are about equal in price.

6. The price of the auxiliaries of the ship (steam pumps, steam steering machinery, turret-turning engines, anchor-hoist engines, hoisting machinery, ammunition hoists, dynamo engines, etc.) is equally increased. But all these machines are very much more expensive in France than in England.

7. The cost of labor in the total for the ships is nearly equal, but since the French workman receives $0.65 per day and the English workman $1.15 per day, it proves that the French ships consumed much longer time in their construction, or, differently expressed, that the French workman produces very much less than the Englishman.

8. The division of labor in English yards is very much better systematized than in France.

9. The English shipyards are arranged very much more practically, and are better equipped than the French yards, as has been stated by the Naval Constructor of the Government yard in Toulon.

Starting from this note Commander Vignot investigates the cost of some ships in regard to the proportion between the cost of material and the cost of labor. The data are arranged in the following table:

IRONCLADS.

Name.	Cost of materials.		Cost of Labor.
	Armor included.	Armor excluded.	
Magnificent, English..... *Hannibal*, English..... *Ocean*, English.....	$320.00 per ton.	$110.00 per ton.	$110.00 per ton.
Brennus, French.....	$2,739,600	$994,600	$899,600
Bouvet, French.....	3,265,200	.....	1,039,600

The armor costs, in England as in France, on an average 450 dollars per ton.

CRUISERS.

Name.	Cost of materials.	Cost of labor.
Pascal, French.....	$477,000	$431,600
Suchet, French.....	410,000	424,000
Bugeaud, French.....	500,000	400,000
Galilee, French.....	278,600	30,800 (?)

Therefore, the cost of the materials and of labor are in France twice as high as in England. On account of these facts, Commander Vignot denounces severely the French Navy Department on account of the faulty organization and employment of labor in shipyards, to which alone he attributes the high cost. He further attacks the usual compilation of the budget, and asserts that this is done only to mislead Parliament and not to inform it, as should be done.—"La Marine Francaise."

PACIFIC CABLE DATA.

Official reports received by Rear Admiral Bradford, Chief of the Bureau of Equipment, from Lieutenant Commander H. M. Hodges, commander of the *Nero*, announce the feasibility of a cable route across the Pacific, connecting San Francisco, Honolulu, Midway Islands, Guam, Luzon and Yokohama. The *Nero* surveyed between Guam and Luzon, and then ran back to Guam, pursuing a zigzag course, in order to sound along the route selected, with a view to obtaining the best possible location for the cable. Then she ran a straight course to Yokohama. She returned zigzagging to Guam, and will zigzag across the line to the Midway Islands and to Honolulu, when her work will be completed.

The *Nero* has found a depth of less than three thousand fathoms between Yokohama and Guam and Luzon and Guam. Three thousand fathoms is the extreme depth the authorities were willing to lay the cable.

The cable between Honolulu and Dongola Bay, which is the Luzon terminus of the cable line, will be 4,812 knots long. Only two offsets from the projected great circle route between the Midway Islands and Guam were found necessary to avoid obstacles to successful laying and operation of the cable. The first was a submarine mountain a short distance west of the Midway Islands, and the second an abyss more than forty-nine hundred fathoms deep, found about five hundred miles east of Guam.

Discussing Capt. G. O. Squier's recent Institute paper, Vice-President Ward, of the Commercial Cable Company, said recently: "He does not allow for a duplicate cable as a part of the government system, and yet no cable system can possibly be successful without a second line. Therefore, the 'reserve fund and interest on capital, $400,000,' and '200 miles of additional cable, $200,000 annually,' as laid down by Captain Squier, must be doubted. The cost per annum will then be:

Total cost of operation of one cable, including maintenance of repair ships, spare cable and reserve fund and interest on capital, as per Captain Squier's figures	$925,000
Reserve fund and interest on capital ($12,000,000) second cable	400,000
Two hundred miles additional cable required annually at $1,000 per mile	200,000
Total	$1,525,000

"This sum is exclusive of extra operating expenses for the second cable, and I doubt if the additional two hundred miles of cable required annually will cost much less than $1,500 a mile."—"Electrical World and Engineer."

THE UTILIZATION OF GARBAGE FOR FUEL.

The recent merger of the leading gas and electric-light companies in New York has led to a discussion in the columns of the "New York Times" which is of so much general interest that the contributions of Messrs. George Westinghouse, Robert H. Thurston and Cary T. Hutchinson are here reprinted:

George Westinghouse.—The bringing together of the gas and electric-light and power interests in New York should result in great advantages to the public and to the interests so combined, provided the latest developments in gas and electric engineering are investigated and availed of. Among the numerous questions affecting the health, comfort and convenience of the citizens of New York (and of all communities, in fact), are three of especial importance, viz:

The disposal of garbage, the abatement of the smoke nuisance, due to the increasing use of bituminous coal for steam-power purposes, and the securing of an adequate supply of water.

From statistics there appear to be created daily in New York about 500 tons of garbage, or at the rate of one-half pound per capita. Such garbage is about 20 per cent. carbon and 80 per cent. water. By a process which has been well demonstrated on a small scale, and which is being rapidly brought to a commercial basis, all of this garbage can be economically, and without offensive odor, converted into a fuel gas of great value. In the same apparatus, and by the same process, soft coal can be made into a gas suitable for power and heating purposes.

The fuel gas made from garbage and soft coal can be used to drive gas engines with electric generators, and the electricity thus produced can be used for light and to drive motors to the exclusion of the thousands of steam engines and boilers which make such demands upon the water supply, since the gas-engine central stations can be so located that the water needed for engine-cooling purposes can be taken from the river.

Bearing upon these questions, and of especial importance, are the partially-executed plans of the electric-power and light corporations, viz: the Metropolitan, Third Avenue and Manhattan Elevated Railways and the New York Gas and Electric Light, Heat and Power Company and the United Electric Light and Power Company. If their present plans, which are fairly well known to the engineering profession, are carried to completion, each will have one large steam station on the East River, between Twenty-ninth Street and the Harlem River, with about 75,000 horsepower of engines, boilers and electric machinery, making an aggregate of 375,000 horsepower, and which may be largely increased when the underground rapid-transit railway is completed, and still further when the electric locomotive is used on all steam railways within the city limits.

If these corporations, which might as well buy electricity as the machinery, coal and water with which to produce it, were to unite in a common plan to provide the electricity needed in their operations by the adoption of the best available methods, the saving to each in capital expenditure would be very great, and the decreased cost of their supply of electricity would make an important addition to their earnings applicable to the pay-

ment of dividends, while, most important of all, the citizens of New York would have solved for them the garbage, smoke and, very largely, the water questions.

I believe the contemplated plans of the corporations above named, which can be shown to be based upon an imperfect knowledge of the subject, will stand in the way of vast public interests, and, so believing, I have said to representatives of some of those companies that the near future would demonstrate the projected power stations and systems of electrical distribution incidental to the character of such stations, to be as far from the best as are the old cable systems for the propulsion of cars.

Dr. Robert H. Thurston.—I have been much impressed by the suggestions of Mr. Westinghouse's letter. It suggests thoughts far more wide reaching than at first may appear. The primary principle which underlies its text is that of the combination of all the essential public utilities in such manner as to insure the most economical production possible. This does not, in this case, mean so much a reduction of total costs to the public as an increase of availability of the product for the average citizen.

When gas is permanently reduced to 50 cents per 1,000 cubic feet we may all use it in our kitchens and, to some extent, for heating and in manufacturing, while the city will employ it in making more extended and efficient the public lighting outside the range of the electric light. When the electric light can be supplied at a half or two-thirds its present average cost, the urban lighting of our communities will be doubled in area and efficiency, and the comfort of honest citizens and their safety and the repression of disorder and crime will be vastly greater than now. As is almost invariably the fact, the reduction of price and costs will be met not so much by saving as by extending the benefits of all utilities. When garbage can be made to contribute to our comfort and health, instead of being a perpetual menace, our householders will find comfort in that fact and our taxpayers will be relieved.

In every city in the country this combination of all sources of power in a single center, and the production of heat, light, power and electricity, and the incineration, profitably and wholesomely, of all garbage, should be provided for. Such a wise and sound method of engineering these enterprises would enable many a small city, or even village, to supply its people with water and light, and to relieve itself from the dangers of typhoid-charged water and of fever-breeding garbage, whereas it must wait many years for the comforts of modern life.

The gas, electric and water-supply plants, and the garbage incineration arrangements should all be combined, not so much to reduce costs of product and of necessary expenditures as to make it practicable for our cities to secure well-lighted streets. an ample supply of pure water—artesian if possible—for drinking and industrial purposes, a complete and useful disposal of refuse matter, and all at minimum charge in the tax levy. But it is the wide distribution of these great blessings rather than the reduction of the aggregate cost to the city of such charges that should be sought.

Mr. Westinghouse has himself done much to render this important change practicable, not simply in his contribution to the art of electric lighting, but also, and more extensively and in a more important degree than is generally realized, in his work in the direction of placing beside the steam engine as a source of industrial power a distinctly dangerous rival in the gas engine of large power, gas engines of 500 and 600, and, in a few instances, of 1,500 horsepower, and operating with exceptional economy, having already been produced. The scheme for the conversion of the potential energy of our garbage into useful power, as a part of the larger plan, is by these facts rendered so much the nearer practicable, and the day of this form of industrial extension so much the closer at hand.

We find ourselves, as Mr. Westinghouse himself has elsewhere stated it, in a "new industrial situation." Happily it is one in which all parties to the present and older situation may be advantaged. The realization of this proposed modernization of the city public utilities in this manner will extend the market

for the sale of electric light and for gas, and thus increase the profits, as always occurs, on the extended business. It will make our very wastes by way of the kitchen door a source of health and profit, and free us from some of the most serious of all the risks and disadvantages of crowded city life. Where it is practicable in the usual case—in fact, to introduce the provision of needed power for a pure-water supply in the scheme, the free use of wholesome water will become a continually growing source of health and comfort and godliness.

Nowhere in the world is there a greater opportunity offered for the full exemplification of this plan and its economical advantages than in New York, and nowhere is it possible to accomplish more for a crowded population than in that city. With pure water in plenty for the poorest, liberal use of electricity for light and power, and of gas, where suitable for lighting, and in the now common and economical forms of gas engine of every magnitude, from 1,500 horsepower down, with sanitary conditions perfected by proper disposal of garbage and sewage, New York should become an ideal residence city. Nature has there done her best, and it only remains for man to do his very best in the light of modern science.

This is hardly less true of all large cities, but that is not the most or the best possible. The larger proportion of our people, so far as urban at all, live in small cities, and these may, under such ideal conditions as are here contemplated, become at a comparatively early stage in their growth well lighted, healthfully provided with water, and sanitarily insured against danger from refuse, now a source of sickness and death, and at a reasonable cost, may be given all the comforts of city life.

Dr. Cary T. Hutchinson.—The letter from Mr. George Westinghouse calling attention to the great advantages that would accrue to the citizens of New York from the use of garbage as fuel, and to what he considers to be the "imperfect knowledge of the subject" shown in the engineering plans for the large power stations about to be erected on the East River, deserves some comment.

Mr. Westinghouse estimates the amount of garbage available daily in New York City at about 500 tons. He implies that this amount of garbage, converted into gas and used in gas engines, would be sufficient to supply a material part of the output of the great power plants that he refers to. Experiments made in England, based on the burning in steam boilers of 26,000 tons of ordinary city refuse, show that one pound of such refuse will make one pound of steam. On this basis, assuming the best engines and electric generators, 25 pounds of refuse would be required for each unit (kilowatt-hour) output of electric energy from the power plant.

Mr. Westinghouse, however, does not propose to use the refuse for making steam, but purposes converting it into a fuel gas. He gives no data as to the value of the refuse used in this way, beyond the statement that "all the garbage can be converted into a fuel gas of great value." It is simple, however, to give an approximate idea of the possible limit to the efficiency of a process of this kind.

Assuming the analysis of the garbage given, that is, 20 per cent. carbon to 80 per cent. water, the maximum theoretical heating value of one pound of refuse is very approximately 2,000 thermal units; if all this energy can be recovered in the form of a gas, that is to say, if the efficiency of the energy conversion from refuse to gas is perfect, and assuming a ratio of 20 per cent. between the energy in the form of electricity, and the theoretical energy of the gas, a high figure, it would require 8.5 pounds of refuse per unit (kilowatt-hour) of electric energy. This figure fixes the maximum theoretical duty of a pound of such refuse when converted into a gas and used in a gas engine. It is not probable that the actual commercial duty of the process will equal 15 pounds of refuse per kilowatt-hour.

That is, a consideration of the elementary principles involved shows a probable duty of 15 pounds of refuse per unit (kilowatt-hour) in comparison with 25 pounds, deduced from extensive tests on steam. This difference represents the possible improvement due to the use of gas engines.

Assuming, then, that a unit of electric energy can be obtained

from 15 pounds of refuse, the 500 tons would yield about 67,000 units. As Mr. Westinghouse truly says, the aggregate power of the large steam plants mentioned is approximately 375,000 horsepower. The daily output of these plants will be approximately 2,500,000 units; in other words, the maximum result that could be got from the consumption of all the garbage of New York City in the way that Mr. Westinghouse describes, would supply about 2½ per cent. of the daily output of power from these stations alone. This is so trifling that it is hardly worth consideration, not being even sufficient to drive the pumps and auxiliary apparatus in the various power houses.—"The Engineering Record."

THE NEW UNITED STATES NAVY-YARD COALING STATION AT NEW LONDON, CONN.

For several years the United States Navy Department has been giving careful consideration to the establishment of permanent coaling stations at the most important strategic points, appreciating the necessity of having an accumulation of coal on hand for emergency, of protecting the fuel from deterioration resulting from exposure to weather, and of constructing mechanical devices to handle coal from store to vessel with the greatest rapidity. The first completed plant of this kind has just been finished at the Naval Station, New London, Conn., by the Hoffman Engineering and Contracting Company, of Philadelphia, Pa., whose designs and specifications were selected by the Department of Yards and Docks in competition with a number of other leading firms of engineers. The building has a storage capacity of 10,000 tons, its general dimensions being: Length, 290 feet; width, 97 feet; height of coal, 35 feet.

As the building was necessarily located near the water's edge, and on unreliable ground, the foundations required careful consideration. After excavation to low-tide level, the entire area was filled with piles, some 1,260 piles being driven. These piles were capped with 12 by 12-inch timber, on top of which was a close grillage of 12 by 12-inch timber. Above this gril-

lage were placed gravel and sand filling, well puddled, and a concrete floor, with a granolithic finish, 12 inches thick. Under the walls and under the center lines of the columns supporting the roof and the railway tracks running through the building, the piles were more closely spaced. The walls are granite-range ashlar, and extend 5 feet 6 inches above the floor. The pitch of the roof is sufficient to prevent the coal from coming into contact with the metal. This is also prevented in case of the central columns by jacketing them with sheet iron and filling the space with carefully-rammed concrete. In no case does the coal come in contact with metal.

The lantern top to the roof protects the railway tracks, which are standard gage, running the entire length of the building, and also contains the mechanism for opening and closing the hatches, besides giving light and ventilation to the building. As shown, there are 14 hatches on each side of the building, each having independent opening mechanism, giving a continuous line of openings available. The covering of the building is corrugated metal and no wood is used in the construction. A concrete sea wall extends the entire length of the building, carrying a single line of rail on which the inshore legs of the conveyors travel. To carry the conveyor machinery it was necessary to rebuild a portion of the dock. Steel piles 80 feet long were required, and they were securely capped and braced with steel beams, angles, etc.

The coal-conveying and handling plant consists of two of Brown's patent bridge tramways, which, in conjunction with the steel shed will enable boats of various sizes and with different numbers of hatches to be unloaded economically and quickly, and the coal transported and deposited into any portion of the coal storage shed. The coal can also be dumped anywhere between the pier and the shed if desired, and transferred direct from small lighters, which can float in the water space behind the pier, to vessels in front of the pier. The coal can also be rehandled through any hatch of the shed to any hatch in vessels or lighters either in front or behind the pier. Coal can also be rehandled from the storage shed by automatic grab

buckets furnished, or it can be shoveled by hand into the dumping buckets.

Bags may also be filled in the building and transported on crates mounted on wheels, and these crates can in turn be lifted through the hatches of the building and conveyed to and lowered through the hatches of the vessels. This arrangement makes it also possible to load or unload any other kind of material anywhere within range of the machines and within their capacity, and this material can be conveyed and deposited to any position within their range, or can be transferred to wagons or cars, or to lighters beyond the pier, or between the piers and the shore. In other words, the hoisting and conveying machinery is not only a complete coal-handling apparatus in itself, but it also constitutes a perfect traveling crane for handling any material along its entire length, as well as over the entire length of wharf over which it travels.

The front piers of these conveyors contain machinery, engine and boiler housed, movable with them, and travel on rails near the front of the wharf, and the rear piers supporting the opposite end of the bridges travel on a rail on the foundation wall at the side of the coal shed. The whole structure, together with the engine and operator's houses, is entirely of iron and steel. All the motions of hoisting and conveying may be performed in either direction at will of the operator. The engine power of each tramway is guaranteed to hoist 3,000 pounds at the rate of 350 feet per minute.

The front piers containing boilers and engines are arranged to be propelled along the dock by power at the rate of from 50 to 75 feet per minute. The back pier is arranged to be operated by hand. Both front and back piers have clamps for fastening them to the rails when necessary. Both piers are mounted on wheels of best chilled charcoal iron ground true to tread. There are ten wheels under each double pier and four wheels are under each single pier. With each bridge is furnished one special 5-ton Fairbanks scale, so located along the length of the tramway that each load carried by the trolley can be weighed while moving along the bridge in its regular course with the scale

beam on top of the bridges, or at any other convenient point. In general, each of the bridges has sufficient power and strength of mechanism to take a loaded bucket from the hold of the vessel, hoist it and transport it to any distance on the bridge tramway, dump and return it to the hold of the vessel in one minute. The general factor of safety for the bridge construction is five for the moving load and four for the dead and wind loads.—"Engineering News."

EFFECT OF CIRCULATION IN WATER-TUBE BOILERS ON EVAPORATION.

At a meeting of the Institute of Marine Engineers held on November 27, 1899, at the Institute premises, Stratford, England, Mr. G. Halliday read an interesting paper on "Experiments showing decrease in the rate of evaporation in consequence of increase in the rate of circulation through the tubes of water-tube boilers." In the course of his paper, Mr. Halliday said: Former experiments were made to see whether molecular change of the water was the cause of the increased absorption of heat by water at the boiling point. We found that at the boiling point there was rather less absorption of heat than at lower temperatures. This was the condition of things when the effects of more rapid motion of the water were eliminated. An attempt was also made to find whether there was a constant increase of absorption of heat by the water as the speed of the water through the tubes increased. It was found that the absorption of heat did rise with an increase of velocity up to a certain point, but after that point in the velocity was reached the absorption fell off, and continued to fall off as the speed of the water through the tube continued to increase. This point in the speed of the water where the maximum rate of absorption of heat occurred was not constant. It varied under the influence of various factors. The speed at which the maximum effect took place rose as the quantity of heat supplied to the tube increased. So did the quantity of heat absorbed rise. The quantity of heat absorbed rose also with the quantity of heat supplied to the outside of the tube.

In those experiments we only dealt with water. We did not deal with water and steam. Steam was not evaporating from the moving water when the results were noted. That being so, it would not be fair to conclude that water while giving off steam behaved in the same way as water did under changes of velocity. Water while evaporating steam might behave quite differently to water alive without steam. Water when evaporating steam does not run through the tube as water, but as water and steam, and therefore the effect of the presence of the steam may change entirely the conditions. What was sought in the following experiments therefore was to apply heat to the outside of a tube through which water was flowing, and note the quantity of steam given off while the water was moving at different velocities. The quantity of heat was also varied and the quantity of steam given off under the different conditions was noted. First of all it may be premised that the accepted view is that the evaporation increases with the rapidity of circulation of water through the tubes; that is, the faster the water runs through tubes it is believed the quicker is the evaporation of steam. This is the universal view with one exception. The "Engineer" has held that this is not true, and that circulation is an evil after a certain point. In the experiments described in the present paper water was heated to boiling in a tank, and drawn from there through a tube heated with a Fletcher burner. The steam and water were separated in a separator and separately measured. First, the flame of the Fletcher burner was kept constant; that is, the heat supplied was kept constant. Under this condition it was sought to determine the influence of the rate of circulation. The rate at which the water moved through the tube was varied. It was sought to determine whether the amount of evaporation remained constant with the heat supplied or varied with the velocity of the fluid through the tube.

The second question was whether the evaporation increased with the speed of the water and steam through the tube or in what way the evaporation was affected by the velocity of the water and steam through the tube. First, then, the tank supplying the water was heated to boiling point, and it gave off

steam freely. Then the Fletcher burner was lit and the flames allowed to play on the copper tube. Then the water from the tank was turned on and allowed to run. After the water had gone through the heated part of the tube, steam and water together flowed through the separator into a flask. After that, the cold water was turned on at the cold-water tank and made to flow through a condenser. By that time the whole of the apparatus was in full working order. The period settled for each experiment was four minutes. At the end of four minutes the water in the flask was measured, and the condensed steam measured also. The sum of the two gave the quantity of water which flowed through the tube for four minutes, and the quantity of steam evaporated for four minutes. After the first four minutes 14 centimeters of water were found in the measure. This meant that 14 cubic centimeters of water had been evaporated during the same time that 175 cubic centimeters of water had flowed through the tube without having been evaporated. This quantity, 175 cubic centimeters, was found at the end of the first experiment in the flask. The total water which had flowed through the heated copper tube was thus 189 cubic centimeters.

When these had been measured the water in each measure was poured away and the apparatus got ready for a second experiment. The flame and the gas supplied to the Fletcher burner were left the same as before. This flame was kept the same through the full set of experiments. To start with, the water and steam were allowed to run right through the separator. As soon as the time to start began the water and steam were shut in the separator by means of the small tap at the bottom, and the flask cleared out. When placed below the separator the water was run into it again, but a little water was always left in the bottom of the separator to prevent steam blowing through. The steam then flowed through the second branch at the top of the separator, got condensed and flowed into the measure. At the end of the four minutes the condensed steam was measured and the water also. The result of the second experiment was that at the end of four minutes 18 cubic centime-

ters of steam had been condensed and 140 cubic centimeters of water had run into the flask. The total quantity of water which had flowed through the copper tube was thus 158 cubic centimeters. Here, then, are two sets of results:

Velocity of water.	Water evaporated.	Velocity of water.	Water evaporated.
93½	23½	54½	24½
94	24	93	23
103	23	122	22
121½	21½	378	18
129	19	575	15
158	18	664	14
189	14	762	12

It will not be assumed that the figures given above show anything but comparative results. A number of factors are purposely left out of consideration, but it may be assumed that the figures show there is not an advantage in a high rate of circulation of water through the tubes of a water-tube boiler.

DETAILS OF THE BOILER EXPLOSION ON THE AUSTRIAN TORPEDO BOAT *ADLER*, JULY 22, 1899.

While on her way from Teodo to Sebenico in the channel of Curzola (nearly 2½ marine miles from Eilande Torcola, and about 6 marine miles from the island of Lesina), on July 22, 1899, a terrible and unexpected boiler explosion occurred on H. M. torpedo boat *Adler*, which killed five men and seriously injured four others. The boat was under the command of Lieut. Camillo Schwarzl and had a crew of fourteen men and two officers. Assistant Engineer Moriz Grabmayr, from Angerheim, Joseph Deotto, the oiler, and firemen and sailors were seriously injured.

The torpedo boat *Adler* was in first-class condition, and had the special mission of training the carrier pigeons. On July 22d, it was to leave Teodo and was due at Sebenico at 7 o'clock in the evening. The boiler was cleaned in Teodo before leaving, and was afterwards filled with fresh water, the supply tank being also filled. The pressure in the boiler was, as usual, kept at 8

atmospheres, although the boiler was made to carry 10½ atmospheres. In the morning the propeller worked at 200 revolutions per minute, and in the evening, when the watch was changed, it was running at 220 revolutions per minute, which increased the boat's speed to 14 marine miles per hour. The first assistant engineer had everything under control and found the engine in a normal condition, the pressure being at 8 atmospheres. The water in the water gages, in both glasses was, as usual, 2 fingers above the normal. The water of the boiler vibrated in the glasses and the water tenders observed the water level every moment, and no steam could be detected escaping either in the fixtures or in the engine. The boiler had a free supply of water which always tasted fresh. On board, the whole crew harmonized with one another. The engineers could be trusted, were competent and did not drink.

On the day of the explosion, to the time of the unlucky event, the sea was smooth. The second officer was on duty, when all at once a terrible report was heard all around for two miles from the ship. The air seemed to be filled for a moment with a dark cloud. Ashes, pieces of coal and iron, water and all kinds of parts of the ship fell down. The falling mass struck the second officer with such force that it crushed his head and he fell dead on deck. The first officer, who at this moment looked out through the port hole, was torn away and never heard of. The second under officer, owing to fright or being scalded, sprang into the sea through the port hole, swam nearly one-quarter of an hour, grasped the life preserver and held tight to it for a moment, when suddenly he disappeared into the sea. The under officer of the boiler was thrown on deck and lay there dead. The storekeeper and one sailor were also missing.

After the explosion the boat presented a terrible sight, the deck over the boiler being totally torn away. Both the bulkheads were bent far apart. The smokestack was bent 30 degrees. The store cabin was hanging on a strip of metal. The forward smoke room was not damaged. The smoke room was torn way from the boiler. The brickwork and walls of the firebox were thrown about. The boiler fittings were torn off. The safety

valve was torn away from the boiler and the main steam pipe was torn away from its place. The pilot house and main steam pipe with the rest of the piping and asbestos all fell. The ash doors were bent and the hinges torn off. The floor plates of fire room were crushed. The air shaft and ventilators were smashed and the engine room bulkheads were bent.

The bricks and firebrick carriers were demolished and scattered. Of the 17-ton boiler, which, under normal conditions carried 7 tons of water, there was no trace, as it had fallen into the sea within a second after the explosion. The fastenings of the ventilators and dynamos were bent in the engine room, and the whole room was filled with dust, soot and ashes. Otherwise the other part of the machinery was uninjured. The material which was on deck right over the boiler—the compass, etc.—disappeared from the boat. The firemen were scattered among the dead and wounded.

Those who revived said that the explosion was the work of a moment. They could not account for what had happened until they saw the whole deck torn up and the boiler missing. After the explosion the bodies were collected and the injured cared for. The officer in command ordered the uninjured to put up a mast, on which a piece of canvas was fastened to serve as a sail, and allowed the boat to drift toward the nearest island, where he landed and informed the life savers. During the night the cruiser *Zenta*, and the torpedo boats *Komet* and *Geyer* came to render assistance and to take the dead and wounded to Spalato.

The torpedo boat *Adler* was hurriedly repaired as well as possible, and towed to Pola and immediately dry docked.

The torpedo boat *Adler* was built in the year 1886 by Yarrow, in Poplar (London). It had a displacement of 95 tons; a total length of 38 meters, width, 4.8 meters, and a depth of 0.98 meters.

The ship's engine consisted of a three-cylinder compound, with a high-pressure cylinder of 18 inches, 825 H.P. At the time of building this torpedo boat water-tube boilers for such boats were not in use. Torpedo boats were fitted up with the locomotive type of boilers, and the firm of Yarrow had under especial

study the construction of said boiler, and it was put in as an experiment. The boiler is built of various materials. It had a copper firebox, and the area was braced by vertical stays of Siemens-Martin steel to stiffen it. The fire tubes were of composition soldered with copper. The whole length of the boiler was 5.515 meters; the diameter of the same, 2.270 meters; the thickness of plate, 16 millimeters; the firebox was 2.590 meters long and 0.914 meters high; the distance between the grate bars and the top of the firebox was 820 millimeters. The two walls of the firebox were held by 261 stays, at a distance of 30 millimeters from each other in order to strengthen the diameter. There were 56 stays holding the front part of the boiler and the wall of the firebox. The total heating surface was 190.42 square meters. The maximum pressure was 10.5 atmospheres. The grate was 1.8 meters long, and had a total area of 3.7 square meters. The weight of the boiler empty was 16,565 kilograms, and the water capacity 6.6 cubic meters. The boiler was arranged for artificial draft, for which ventilators and blowers were installed in the fire room.

The torpedo boat *Adler* was the fastest boat at sea in her time, and was looked upon as a wonder by shipbuilders. At her speed trials she developed 22.3 knots per hour. During later trips the engine indicated 340 revolutions per minute, with 1,060 H.P., and 305 revolutions, with 736 H.P., when the total coal consumption was only 670 kilograms per hour.

To-day the boiler lies at a depth of 60 meters under the sea. The exact location is not known, as the compass was blown away by the explosion. The boiler was properly cleaned before departing, but there was always a feeling that the firebox would probably give away at the back, and a quantity of rivet-heads and rivets were found in the boiler room. About a month before the accident the boiler was inspected and put under hydraulic test, with good results.—Translation.

RESEMBLANCES BETWEEN ANIMATE AND INANIMATE MATTER.[1]

It is becoming increasingly difficult to draw a line between the phenomena of life and those of dead matter. Extremists, of

course, go so far as to say that there is no difference; but even those who contend for a rigid distinction admit the discovery of interesting facts that furnish analogies between the organic and non-organic worlds in totally unexpected places. Some of these are brought out by M. C. E. Guillaume in a recent paper read before the Swiss Society of Natural Sciences, of which the following abstract appears in the "Journal de Genève":

"At bottom, the abyss that seems to separate brute matter from living matter does not exist, and the more deeply we investigate intermolecular phenomena, the more analogies we find with those of biology. Whether it forms part of a living or non-living body, the molecule undergoes multiple metamorphoses, more or less rapid disaggregations, movements, etc. The metamorphoses of non-living matter, ordinarily very slow, are always adaptations to varying conditions, just like the transformations of the living organisms, properly so called.

"The microscope, which has opened up such vast regions in the mechanism of fermentations, for example, by enabling us to connect this with the action of determinate microorganisms, is in the way of rendering an equally great service in its application to inanimate matter.

"The form of this latter, taken in a solid state, is not variable. Every one knows that glass contracts with temperature, that all bodies acted on by external force are deformed, and that brass, for instance, under the influence of heat, passes from the ordinary to the annealed state.

"Modern physics shows us that ordinary brass is composed of little broken crystals, mingled with a mass which they penetrate completely. In annealed brass, on the other hand, the crystals are reconstituted and separated from the amorphous mass. Now these crystals could not have been formed without a movement of the molecules in the interior of the metal—a movement that is much greater than ordinary molecular motion, reaching hundredths, and even tenths of a millimeter,"

Where, asks M. Guillaume, does the mobility of the molecules in a solid body have its limit? It is doubtless greater, he believes, than has usually been supposed. At the temperature of

100 degrees, a small cylinder of lead, in contact with a disk of gold for forty days, has, at the end of that time, gold throughout its whole mass. The astonishment that such an experiment excites grows less, the writer reminds us, when we compare the result with the long-known fact of the penetration of carbon into heated steel. When we add external to molecular forces, we get effects of still greater intensity. To quote again:

"In facts of this kind, which modern discovery is multiplying daily, M. Guillaume finds the proof of molecular displacements measured by millimeters and centimeters; it is then wrong to draw a line between so-called inert matter and animate matter.

"On the other hand, brute matter is modified by adaptation. When we subject a steel bar to a pull sufficient to break it, a narrow neck is first formed at the point where the bar will break. But if we cease pulling as soon as the narrowing becomes noticeable, and then turn the bar down to a uniform diameter in a lathe, when we subject it a second time to this treatment, we shall find that the neck always forms in a new place. It appears that wherever, under traction, the metal begins to be thinner, the substance 'instinctively' hardens to resist the effect.

"In the alloys of nickel and steel studied by M. Guillaume, similar facts have been brought out. * * * We can mention here only one—the fact that under the influence of great cold, bars of nickel-steel lengthen in such a way that when the phenomenon is seen for the first time it seems as if the inert matter had been suddenly endowed with life.

"Phosphorescent bodies, from the point of view of adaptation to external circumstances, furnished an analogy with social organization. M. Guillaume cites a beautiful example taken from Becquerel's process of color-photography. Chlorid of silver, which becomes red under the influence of red light and green when subjected to green light, is only, by this process, protecting itself against the light, which tends to break up its molecule.

"In closing, M. Guillaume, after indicating the likenesses that appear to exist between inert and animate matter, takes care to

remind us of some of the fundamental facts that forbid us to believe that these forms of substance are one and the same. It would, of course, be imprudent to generalize prematurely, but M. Guillaume has certainly shown us analogies where they would have been least suspected."—Translations made for "The Literary Digest."

STORY OF THE *CHARLESTON* DISASTER.

In the reports from Manila, relative to the loss of the U. S. cruiser *Charleston* off Camiguin, the accident is said to have been due primarily to the inaccuracy of the Spanish charts. It is claimed that Spanish charts of the Philippine waters are full of inaccuracies and are not to be trusted. In heading for the island of Camiguin, the navigators on the *Charleston* were governed by a chart which showed two small pinnacle rocks sticking straight out of the water about eighteen miles from the island to the northeast. The chart showed these pinnacles as about six miles apart, with clear water between them. As the *Charleston* approached this vicinity she was steaming a little less than 5 knots an hour, and there was a current setting her along at 4 knots. As the cruiser approached the pinnacles, those on board noticed confused water ahead of them. This was supposed to be a tide rip, of which the sailing directions spoke, and Captain Pigman gave the navigator the order "Port your helm. It is easier to go around a tide rip than it is over a reef." The helm was put over hard immediately, but the fact that the vessel was running at a slow rate of speed prevented a response as quickly as would otherwise have been possible. Indeed, it has been stated by officers who were on board that the disaster might have been averted had the vessel been running at a greater speed.

The *Charleston*, as she swung off to starboard was borne down on the rocks, located at the supposed tide rip. The commander, anticipating what was coming, gave the order to reverse the engines at full speed, and this was done instantly, but time was not allowed for the cruiser to gather sternway and she struck heavily on the port bow, gave a sharp list to port, scraped along,

bumping over the jagged rocks, and stopped, held fast by the reef. The engines were kept in operation at full power and did all they could to back the vessel off, but so far as fore-and-aft movement was concerned she never budged.

The discipline on board when the vessel struck is said to have been perfect. The men were at work closing the watertight doors before Chief Engineer Little, who had been asleep, could get to the engine room, and they shut them so quickly that one man was shut up in the hydraulic room. It was realized almost from the first that the vessel would have to be abandoned. The vessel pounded in a frightful manner, the swell lifting her and dropping her repeatedly with great force on the jagged rocks. The boilers were lifted from their fittings, and all but cast adrift. There was no delay in coupling up the pumps and setting them going; but all the pumps, first the 6-inch and later the 12-inch, were hopelessly clogged by the coal which had been washed down into the bilges. The rush of incoming water finally reached the forward fire rooms, and the hands of the steam gages slid down to the left with a rapidity which soon made it necessary to abandon the big pumps for want of steam. The steam ran down to 30 pounds, and then the air pumps stopped, while a dimming of the electric lights indicated plainly to all on board that water had reached the dynamo room. Even then the engine-room force stuck to their work, vainly striving to operate some of the pumps by hand and with the light of oil lamps.

The men on the *Charleston* were all taken off safely, although the fact that the vessel had lost one of her boats made the work difficult. After the shipwrecked crew had been rescued by the *Helena*, a steam launch made another trip to the *Charleston*, but it was found to be impossible to get aboard. The cruiser had settled by the stern until the after bridge was awash, and it was evident that it was simply a question of a little rough weather when she would go down. The general opinion is that the court of inquiry will find that no blame attaches to the *Charleston's* officers for her loss.—"Marine Review."

THE WEAR OF GEAR TEETH.

The correct form of gear teeth is a subject to which probably more study has been given than almost any other detail of machine design, and from the time which is given to it in some courses of study it might almost be supposed that the tracing of tooth outlines was the main object of the mechanical engineer. In all these studies, however, one important feature of gear-tooth action has hardly been considered, namely: the influence of the shape of the tooth upon the wear. Several years ago a paper upon this feature was presented before the American Society of Mechanical Engineers by Professor Reuleaux, and now we have a very full treatment of the same subject in a series of papers by Herr O. Lasche in the "Zeitschrift des Vereines deutscher Ingenieure."

The importance of this matter is shown by the fact that electric traction and other applications of electric driving have led to a much wider introduction of high-speed gearing than has heretofore been made, and in many instances these applications are surrounded by conditions which conduce to rapid wear.

It is evident that the question of wear compels the consideration of many other conditions than those involved in the mere kinematic problem of the transmission of motion at a determinate velocity ratio, the wear depending upon the pressure on a given unit of the tooth surface, upon the extent and nature of the sliding, and upon other working conditions to be considered in each specific case.

Heretofore the best form of tooth outline has been decided solely by the theory of geometrical relation of the parts during the transmission of motion, but when the question of wear is taken into account it will be seen that the form of tooth may have an important influence upon the life of the wheel.

The two forms considered by Herr Lasche are the epicycloid and the involute, these curves, or some close approximation to them, being practically the only ones in general use. Assuming that these are practically equal, so far as ease of construction and correctness of transmission of motion are concerned, he takes up the difference in wear in each case, giving some

very interesting and instructive diagrams. The wear may be considered as dependent upon the following three conditions: the specific pressure of the two tooth surfaces upon each other, the cofficient of friction of the materials used, and a coefficient depending upon the extent to which the two surfaces roll and slide upon each other.

Assuming the total pressure to be uniform during any period, the specific pressure depends upon the area over which the total pressure is distributed, and it is evident that this area is governed by the curvature of the surfaces. If the materials were absolutely inelastic, there would be but a line contact in any case, but in practice the area of contact depends upon the elasticity of the material and the radius of curvature of the surfaces. Since the curvature is by no means constant for either form of tooth, it follows that the specific pressure varies during different portions of the engagement of the teeth, and there will be variations in wear upon different portions of the tooth from this cause.

The question of relative sliding and rolling action is carefully studied by Herr Lasche, large diagrams of teeth of both forms being shown with the faces divided so as to show the extent to which the sliding occurs, and the relative results being plotted in the form of curves. Similar curves are given to show the varying pressure at different points of engagement, and by combining the two curves the extent and distribution of the wear can be theoretically deduced.

From these it is seen that the wear on involute teeth should be much more irregular than of epicycloidal curves, the pressure and rubbing being especially high at the beginning of engagement in the case of the former.

Comparing these theoretical conclusions with the behavior of teeth in practice, it will be seen that the theory is well borne out. A number of photographs are given of gear teeth which have been badly worn in service, and the distribution and extent of wear in the two systems show that it is quite possible to determine beforehand the character of action for a given form of tooth, so far as durability is concerned.

The question of the "coefficient of wear," first introduced

by Reuleaux, is a matter which should undoubtedly be taken into consideration in connection with the whole subject of gear design for such service as is involved in tramway work, and with an intelligent study of the subject a much longer life for gear wheels may be expected.—"Engineering Magazine."

TABLE SHOWING THE LOSS OF PRESSURE IN STEAM PIPES.

[By A. F. Nagle, M. Am. Soc. M. E.]

1 Boiler Horsepower = 34.50 pounds of water evaporated from and at 212 degrees Fahrenheit per hour. Formula [Kent, page 617]:

$$p_1 - p_2 = \frac{Q^2 w L}{C^2 d^5}.$$

p_1 and p_2 = pressures at beginning and end of pipe,
Q = cubic feet of steam per minute,
w = weight of one cubic foot of steam,
L = length of pipe in feet = 100 feet,
d = diameter of pipe in inches,
C = constant = 65 or $C^2 = 4{,}200$.

This formula will reduce to

$$p_1 - p_2 = \frac{.00787\, V \times H.P.^2}{d^5},$$

when V = volume in cubic feet of one pound of steam at required pressure, and $H.P.$ = horsepower.

For 100 pounds pressure $V = 3.82$
" 150 " " $V = 2.72$
" 200 " " $V = 2.12$
" 250 " " $V = 1.73$

The formula then becomes for

100 pounds steam pressure, $p_1 - p_2 = \frac{.0300\, H.P.^2}{d^5}$;

150 pounds steam pressure, $p_1 - p_2 = \frac{.0214\, H.P.^2}{d^5}$;

200 pounds steam pressure, $p_1 - p_2 = \frac{.0167\, H.P.^2}{d^5}$;

250 pounds steam pressure, $p_1 - p_2 = \frac{.0136\, H.P.^2}{d^5}$.

LOSS OF STEAM PRESSURE IN FLOWING THROUGH 100 FEET OF PIPE.

Boiler, H.P.	Diameter of pipe, inches.	Steam pressure, pounds per square inch.			
		100.	150.	200.	250.
100 H.P.	2½	3.0	2.2	1.7	1.4
	3	1.2	.90	.70	.57
	3½	.57	.40	.32	.27
200 H.P.	3	5.0	3.6	2.8	2.3
	3½	2.3	1.6	1.3	1.1
	4	1.2	.84	.66	.54
300 H.P.	4	2.6	1.8	1.5	1.2
	4½	1.5	1.1	.83	.68
	5	.86	.62	.50	.40
400 H.P.	4½	2.6	1.9	1.5	1.2
	5	1.5	1.0	.88	.72
	6	.62	.44	.35	.30
500 H.P.	5	2.4	1.7	1.4	1.1
	6	.97	.69	.54	.45
	7	.44	.32	.25	.21
600 H.P.	5	3.5	2.5	2.0	1.6
	6	1.4	1.0	.78	.65
	7	.64	.46	.36	.30
800 H.P.	6	2.5	1.8	1.4	1.2
	7	1.2	.82	.64	.53
	8	.60	.42	.33	.28
1,000 H.P.	7	1.8	1.3	1.0	.83
	8	.91	.66	.51	.42
	9	.51	.36	.29	.23
2,000 H.P.	9	2.1	1.5	1.2	.94
	10	1.2	.86	.67	.56
	12	.47	.33	.27	.22
3,000 H.P.	10	2.7	2.0	1.5	1.3
	12	1.1	.75	.61	.50
	14	.50	.36	.30	.23
4,000 H.P.	10	4.8	3.5	2.7	2.3
	12	1.9	1.4	1.1	.88
	14	.90	.64	.50	.42
5,000 H.P.	12	3.0	2.2	1.7	1.4
	14	1.4	1.0	.80	.65
	16	.75	.53	.41	.34
7,500 H.P.	14	3.2	2.3	1.8	1.5
	16	1.7	1.2	.90	.75
	18	.90	.63	.50	.42
10,000 H.P.	16	3.0	2.0	1.6	1.4
	18	1.6	1.2	.90	.74
	20	.94	.67	.53	.44

—"Engineering News."

THE LINOTYPE MACHINE—WHAT IT DOES AND HOW IT WORKS.

Mr. Morris Fulton, in describing the linotype in a letter to the "American Machinist," says: The *linotype* makes *lines of*

type. The operator has a finger board like the finger board of a typewriter, and he operates it in about the same way. When he has touched off all the letters for the words of a line, touching a key also for each space between the words, and when his work for the line is thus completed, he begins again with the next line, and so on, without waiting at all for anything to happen or to be done. He attends to his business and the machine attends to its. And that the machine is attending to its business is soon in evidence. Before the operator's manipulations for the second line are completed the machine delivers a brand new and perfect casting of the first line.

We all know well enough how ordinary printers' type looks. Well, here's a line of bran new type all frozen together into a single solid block, or at least it looks like that; but instead of a lot of type the line produced is really a stereotype or casting of a line of type, identical in shape and in every dimension with a line of actual type, so that it is not at all like the thin plates of the usual stereotypes or electrotypes, which have to be mounted on wooden blocks of the proper thickness before they can be used. The linotype is complete in itself, and ready for immediate use in making up a form with other type, with cuts or half-tones, or anything else as may be required.

The linotype machine is not a type-setting or a type-distributing machine. It discards the use of printers' type entirely in its operations, and, in fact, supersedes and does away with the great invention of Gutenberg. What the machine really handles are matrices or molds for forming the faces of the letters or other characters, one matrix for each such character, and these remain in the machine, are constantly automatically redistributed, and are used over and over again.

Several of the matrices for each letter or character used are, of course, always in place in the machine, waiting for the touch of the operator. Each descends by its own channel when its key is touched, these channels being vertical at first, but curving and converging towards the left as they descend, the matrix being finally dropped upon a swift-running inclined belt, which lands it in its place in the line that is being formed. These

matrices are not much more than an inch long, and are made of brass; while the spacers that come between the words are four or five inches long and are made of steel. The spacers are tapered sidewise, and when all the words or syllables are in the line and the length of the line is still not quite filled, these taper spacers are all advanced together until the line is of the required length, so that then all the spaces in the line are of the same width, and linotype work is thus, therefore, always more correctly spaced or justified than hand work can ever be. This justification of the line is attended to automatically by the machine after the operator has completed his work upon it.

The machine has a constantly-running electric motor and also a pot of melted type metal, heated by gas and kept constantly at the proper temperature. When the operator has completed his line, and wants to go on with the next, his right hand brings down a lever which lifts the line of matrices and spaces about six inches and entirely out of his way. The same movement of the lever operates a clutch which sets in motion the main cam shaft, one revolution of which produces a complete cycle of the operations involved in casting and delivering the linotype and in redistributing the matrices and spacers.

This cycle of operations goes on, after it is once started, entirely regardless of whether the operator goes on with his keyboard manipulation or not. The line is first slid to the left and then it goes vertically down out of sight, and here the linotype is cast. The matrices, it will be remembered, contain on their bottom faces the molds for the formation of the faces of the type. The mold for the body of the linotype is a permanent part of the mysterious and invisible region where the casting goes on. I am, of course, only telling here what can be seen by a casual onlooker, and not one specially instructed in the details and intricacies of the mechanism. After disappearing for about five seconds, during which the casting has been done, the line of pieces rises into sight again, and is carried, say, six inches higher than on its previous lateral movement before descending. At this level it is slid to the right, a long arm comes down and hooks over the matrices, lifting them out by hooking over the tops of

them, which are wider than the spacers, and they are swung to the top and back of the machine and slid off to the right, to be dropped into their respective receptacles, ready for use again as soon as the touch of the key releases them.

The distribution is accomplished by simply jogging the matrices along to the right, which is done by a constantly-running mechanism, the matrices being endowed with the power of each selecting its proper opening at which to drop. This is accomplished by the differences in certain notches which are cut in the tops of the matrices, the combination being different for each letter or character employed. The spacers, which were left when the matrices were lifted out, are simply slid to the right, which leaves them all ready to successively drop down into the line when the space key is touched, and this is all the distribution required for the spacers. Before the completion of the cycle of operations the cast and finished linotype is delivered close to the operator's hand.

The time for the entire cycle of operation is only about ten seconds, and if the operator is working lively there may be only a second or two between the completion of one cycle and the beginning of the next. The cam shaft always comes to a standstill at the completion of its rotation, and remains so until started again by the operator. The line of type which is being set up is always close to the free sight and touch of the operator, so that he can see and know precisely what is going on, and he can insert or remove characters as he will, or make any corrections by hand as well as when setting common type. The machine is not to be run by a child or by one who can simply finger the keyboard, but for one fully accustomed to its ways it does marvelously correct and beautiful work, and a lot of it.

FALLING SPEEDS FOR SHORT DISTANCES.

[By Oberlin Smith.]

Although the speed of falling bodies (disregarding air-resistance) is, of course, easily calculated by the ordinary formula, $T=\sqrt{\frac{H}{16.08+}}$, wherein T represents the time in seconds and H

the height in feet through which the body will fall, it is sometimes convenient to save one's self the trouble of calculation and to refer to a table, hoping to find therein the particular values required.

Such tables are not very common and, where found in books, usually refer to the number of feet through which the falling of a body takes place during the first, second, and perhaps each succeeding one. The writer, however, has never happened to see published a table giving the time of falling for motion expressed in minute fractions of an inch.

He has, therefore, modified the ordinary formula as follows: $T=\sqrt{\frac{F}{193}}$, wherein T equals the time in seconds and F the falling height in inches. The table appended below may probably be of use to some of the readers of the "American Machinist," as it has been to the writer. He has based it upon the formula and made it give the falling time in thousandths of a second for each one-hundredth of an inch up to .10 inch, thence by

TIME REQUIRED FOR A BODY TO FALL (DISREGARDING AIR RESISTANCE).

F	T	F	T	F	T
.01	.007	1.10	.075	10	.228
.02	.010	1.20	.079	11	.239
.03	.012	1.30	.082	12	.249
.04	.014	1.40	.085	15	.279
.05	.016	1.50	.088	18	.305
.06	.018	1.60	.091	21	.330
.07	.019	1.70	.094	24	.353
.08	.020	1.80	.096	30	.394
.09	.021	1.90	.099	36	.432
.10	.023	2.00	.102	42	.466
.15	.028	2.25	.108	48	.499
.20	.032	2.50	.114	60	.557
.25	.036	2.75	.119	72	.611
.30	.039	3.00	.125	84	.660
.35	.042	3.50	.135	96	.705
.40	.045	4.00	.144	108	.748
.45	.048	4.50	.153	120	.788
.50	.051	5.00	.161	132	.827
.60	.056	5.50	.169	144	.864
.70	.060	6.00	.176	156	.899
.80	.064	7.00	.190	168	.933
.90	.068	8.00	.203	180	.966
1.00	.072	9.00	.216	192	.997

twentieths of an inch up to .50 inch, thence by tenths of an inch up to 1 inch, and so on, by increasing the changing intervals, up to 192 inches, or 16 feet. At this point it will be noticed that the time is, as it should be, very nearly one second.

The utility of a table of this kind, worked out so much in detail, will not be apparent to the astronomer or artillerist, but it has proved practically useful in determining the speed at which certain small members of quick-working machines tend to fall. This is especially the case in regard to the time in which certain pieces of work will fall after being delivered from the tools which operate upon them, when it is required that gravity shall act as a "discourager of hesitancy" to make them get out of the way thereof, ready for the next operation in the machine. An example of this is shown in certain automatic presses and dies, where the pieces of work ejected from a die must be removed within a given time to clear the way for a succeeding piece. Sometimes gravity is found to be sufficiently rapid for this purpose. If it does not prove so, then other means, as magnetic attraction, an air blast or a mechanical push-out, have to be provided.

It might, perhaps, for some purposes, be necessary to amplify the table in question by making none of the steps between the figures greater than one inch, and continuing the small fractions further along from the beginning. The writer, however, has not, so far, found the need for anything of a more detailed character than the figures as given. Approximate intermediate distances can usually be guessed at with sufficient accuracy.

COMPARATIVE COST OF RAILWAY TRACK IN 1898 AND 1899.

The accompanying table is taken from a small pamphlet issued by Mr. Francis How, 11 William street, New York City. It shows the approximate cost of a mile of railway track in December, 1898, and December, 1899. For rails and fastenings actual market prices have been taken; and figures representing average conditions have been assumed for ties and ballast. Rails are taken at $20 per ton in 1898 and $35 per ton in 1899. Spikes

were $1.50 per 100-pound keg in 1898, and $3 in 1899. Comparative prices on other items are:

	1898.	1899.
Angle plates, per 100 pounds	$1.20	$2.75
Bolts and nuts, per 100 pounds	1.70	4.00
Braces, per thousand	20.00	30.00
Washers, per thousand	8.00	10.00
Ties, each	.50	.75

For 56-pound rails, 28-pound splices are used, and this is increased to 40 pounds for 70-pound rails, and 45 pounds for 90-pound rails. For the light rails 2,640 ties per mile are assumed, and 3,000 per mile for the heavier rails.

APPROXIMATE COST OF RAILROAD TRACK PER MILE IN DECEMBER, 1898, AND DECEMBER, 1899, EXCLUSIVE OF GRADING, CULVERTS, BRIDGES, ETC.

.....	Weight of rail.					
	56 pounds.		70 pounds.		90 pounds.	
	1898.	1899.	1898.	1899.	1898.	1899.
Rails	$1,760.00	$3,080.00	$2,200.00	$3,850.00	$2,828.00	$4,950.00
Spikes	90.00	180.00	99.00	198.00	99.00	198.00
Angle plates	118.27	271.04	168.96	387.20	190.08	435.60
Bolts, nuts, etc.	55.50	98.00	77.40	141.00	82.40	146.00
Ties	1,320.00	1,980.00	1,500.00	2,250.00	1,500.00	2,250.00
Track laying	500.00	575.00	600.00	690.00	600.00	690.00
Ballast	300.00	360.00	900.00	1,050.00	1,500.00	1,800.00
Total	$4,143.77	$6,544.04	$5,545.36	$8,566.20	$6,799.48	$10,469.60

—"Engineering News."

NAVAL REQUIREMENTS FOR AMERICAN-BUILT MERCHANT VESSELS.

The Navy Department has arrived at an understanding with the William Cramp and Sons regarding the construction of merchant steamers at the works of that company, in order to have them comply with the intent of the Act of March 3, 1899.

In case of sudden emergency, as has been recently demonstrated, the Government would be put to much expense and delay in the conversion into auxiliary cruisers of vessels not fulfilling these requirements. To avoid this seems to be the intention of the law, and the following general features will be embodied in the construction:

1. To have all fire mains and steam and exhaust pipes to steering engine below the water line. Fire mains to be fitted with risers controlled by valves below water line, sufficient in number for each compartment. Steam and exhaust pipes for all auxiliary machinery to be controlled by valves below water line.

2. Efficient watertight subdivisions.

3. All classes of vessels shall have efficient ballast and trimming tanks to compensate for omission of cargo and consumption of coal when used as men-of-war.

4. All vessels of first and second classes shall be fitted with a complete double bottom with efficient subdivisions and means of flooding and draining same.

5. All compartments and tanks shall be fitted with efficient pump connections.

6. The boilers and engines, when possible, shall be placed below the water line and shall have efficient coal protection both at sides and fore and aft.

7. Special consideration shall be given to the arrangement of decks, hatches and cargo spaces to facilitate location of battery and magazines. Efficient stiffening of structure shall be provided for their proper and speedy installation.

8. All vessels of the first class shall have the steering gear and rudder head below the water line.

9. The water line referred to in these requirements is not to be considered the load water line of the merchant vessels, but the load water line of the vessel when used as an auxiliary cruiser.

COALING SHIPS AT SEA.

The problem of coaling ships at sea has been fairly satisfactorily solved by the Miller Coal Conveyor (an invention of Mr. Spencer Miller), recently tested aboard the *Massachusetts* in connection with the collier *Marcellus*. On December 21st a smooth-water trial was conducted off New York Harbor, outside of Sandy Hook Light. In less than an hour and a half from the time the boat was lowered from the *Massachusetts* to convey

the towing line to the *Marcellus* everything was secured in position and delivery of coal begun. A speed of six knots was continued during this test, and an average of nearly 19 tons per hour delivered. As was natural to expect, a number of minor adjustments had to be made, owing to every one being unfamiliar with the handling of the apparatus, but on the whole the results were eminently satisfactory.

On December 23d a test was made in what was termed "moderate" weather. A wind characterized as "moderate to stiff" was blowing, and the sea was such as to cause the ships to roll moderately. The attachment of the towing line and conveying lines was completed in about an hour and a half from the time the first boat was lowered, and it was made evident by the test that coaling could be carried on in any sea in which the towing line could be conveyed from one ship to the other in small boats safely. In fact, the experiments during this weather resulted in transferring an everage of 20.3 tons per hour, and on the same day varying the course of the ships so as to bring the sea abeam, and in other directions even a higher average was maintained for a short period, the ships at one time pitching considerably and rolling from 4 degrees starboard to 3 degrees port. When the sea was abeam the collier was rolling 5 degrees on either hand, the maximum roll observed being 7 degrees to starboard and 6 degrees to port. Under this latter condition a 15-minute test resulted in a rate of 22 tons per hour. The speed of the ships during the last trial was about 5 knots.

It will thus be seen that the particular direction of the sea relative to the ships did not materially alter the amount of coal possible to deliver.

The suggestion was made that it might be a preferable arrangement to have the collier tow the ship to be coaled, as with all men-of-war it is preferable to have the coal delivered forward instead of aft, the arrangements generally being such as to expedite the removal from the delivery chute to the bunkers from the bows rather than from the stern. This, as yet, has not been experimented with.

The apparatus was partially described in the November JOURNAL, but a fuller description is here given at the risk of some repetition.

It is proposed, with this device, to have the distance between ships about 300 feet; this method of securing boats at sea is recognized as being safe.

The warship to receive the coal will erect a pair of shear poles on its deck, which, secured by guys, will support a sheave wheel and a chute to receive the load.

The collier is provided with a specially-contrived engine located aft the foremast, having two winding drums. A steel cable $\frac{3}{4}$ inch in diameter, leads from the drum to the top of the foremast, over a sheave, thence to the sheave on the warship, back to another sheave on the top of the foremast, thence to the other drum. This engine gives a reciprocating motion to the conveying rope, paying out one part under tension; a carriage secured to one of the parts passes to and from the warship, its load clearing the water intervening.

A carriage of special form is provided with wheels which roll on the lower part to the conveying cable, and grip slightly but sufficiently the upper part of the cable. This carriage will carry bags of coal 700 pounds to 1,000 pounds. The load is held by a hook pivoted at the bottom of the carriage, which hook is held by a latch. When the carriage comes in contact with the rubber buffer on the sheave block at the warship, this latch is pressed in, thereby releasing the hook and its load. Should the carriage strike heavily at either terminus, the upper part of the cable will slip through the grip and no damage will be done.

As soon as the bags are dropped the direction of the rope is reversed and the carriage returned to the collier. During the transit of the load an elevator car descends to the deck of the collier, bags of coal placed thereon, suspended from a bale, and elevated again to the stops on the guides, so that when the carriage has returned to the collier the pointed hook finds its way under the bale or hanger supporting the coal bags. The instant the load is hooked on the direction of the ropes is again reversed, the carriage takes its load from the elevator and transfers it

across the intervening space to the warship and drops it again into the chute.

The engine for operating the conveyor is of peculiar construction. It runs practically all the time in one direction, its speed being varied by the use of the throttle. The drum near the foremast is provided with friction mechanism, so that it is capable of giving to the rope a tension anywhere from 1,000 pounds to 4,000 pounds. This drum is operated by a lever. The other drum is of special form, employing two dry metallic surfaces in contact. This drum is adjusted so that it will slip under any strain exceeding, say 3,000 pounds. It may be adjusted while the operation is going on, the tension being increased if the load sags too much and diminished if the deflection is unnecessarily small. The forward drum will be referred to hereafter as the 4,000-pound drum, and the other as the 3,000-pound drum.

When the engine is running, the tendency of both drums is to draw both parts in, one to the extent of 4,000 pounds and the other 3,000 pounds. The effect, therefore, is for the 4,000-pound drum to prevail and overhaul the 3,000-pound resistance, and it is this resistance that sustains the load in its transit between the two boats. Through the co-operation of the two drums, the conveying distance between the two boats is compensated for and a practically uniform tension sustained during the transit of the load. If the points of support on the two ships approach each other (during the transit of the load), the effect will be that the drum pulling 4,000 pounds will take up the slack so produced, and the 3,000-pound drum will temporarily cease slipping, or at least the slip will be reduced. If, now, the boats pull apart, the 3,000-pound drum will simply slip the faster. All that is necessary, therefore, in the operation of this machine is to see to it that the speed of transit is in excess of double the speed at which the two boats come together.

After the load is dumped at the warship the operator of the engine releases the friction lever on the 4,000-pound drum, thus reducing the tension on the lower part to some point considerably below 3,000 pounds, whereupon the 3,000-pound drum acts to haul in rope, and thus returns the carriage to the collier.

The speed of conveying is about 1,000 per minute, consequently the load will be taken from the collier and deposited in the warship in about 20 seconds.

Attention is called to the fact that the total tension on these two parts of rope will never exceed, say 8,000 pounds; furthermore, should the ships pull away from each other and the towline part, the only effect will be to unwind the rope frome one of the drums, its end falling into the water, whereupon the other drum will wind in the other end of the rope and recover the carriage attached thereto. The drum used for operating the conveyor serves to wind up and store the cable when the collier is not coaling at sea.

An auxiliary rope known as the "sea-anchor line" is stretched above the two parts of the conveyor line and under a pulley on the carriage. This rope is attached by a "knock-off hook" to the superstructure of the warship, and rests in a "saddle" on the shear head; thence it leads through the carriage, over, pulleys at the head of the foremast and mainmast of the collier and on astern several hundred feet to the sea. On the end of this rope a drag or "sea anchor" is attached, made of canvas in the form of a cone. This sea anchor is selected in reference to the speed with which the ships are to travel. In a smooth-water test, speeding at six knots, a drag 7 feet in diameter at the base was used. During the rough-weather trial the same anchor semed to give the required tension at five knots.

This line is to support the carriage when empty, on its return to the collier. It permits the conveyor line to be slack and prevents the overturning or twisting of the carriage. Doubtless at times it helps also to support the load in transit across, but photographic views, taken during the passage of the load, show the sea-anchor line slack, thus demonstrating that the tension device on the conveyor line is sufficient to sustain the load at a sufficient elevation during its transit.

LIMITATIONS OF THERMODYNAMICS.

An important paper has recently been issued from the press of Dunod as a reprint from the "Revue de Mécanique," in which

M. Georges Duchesne presents the results of a very extensive experimental study of the thermal and thermodynamic processes in operation in the steam engine, and especially during the period of emission, which has been the most difficult of investigation and the most obscure of all the elements of the vapor-engine cycle.

With a vapor engine in steady operation the observation of the amount of liquid passing through the system in the unit of time gives the measure of the quantity taken into the working cylinder at each stroke of its piston, and this, with the determination of "quality" by the "calorimeter," and automatic registration of volumes and pressures by the "indicator" of Watt, permits the exact apportionment of energies and the physical condition of the fluid to be determined from the instant of closure of the induction valve to its opening at the commencement of exhaust. The delineation of the "saturation curve" on the indicator diagram, for the quantity of fluid known to have entered the cylinder gives the measure of contemporaneous volumes of the corresponding quantity of "dry and saturated" vapor, which serves as the unit of the scale measurements of the relative volumes, and weights of liquid and vapor in the mixture constituting the working fluid, or the extent of superheating, if at any point superheated. From the instant of commencement of emission, however, no measure is obtainable of these quantities and the problem becomes incapable of solution by ordinary observation.

Donkin has sought the solution of this particular question of the state of the vapor in the period of emission and that of compression by the use of his "revealer," by means of which the fluid is sampled and tested as to quality, and Professor Carpenter, in the laboratories of Sibley College, has sought the same end by the use of the now familiar "steam calorimeter," taking off samples of the steam automatically at certain points in the portion of the cycle to be investigated. Donkin concluded that the vapor in the exhaust period was wet; Hirn, Carpenter and others, including Dwelshauvers-Déry, have found it dry. M. Duchesne revises the work of Donkin, particularly, and concludes that, con-

trary to the deduction of the investigator himself, the research indicates that the vapor is dry and saturated during the period of emission. He decides that the results of those experiments furnish "proof of the complete dryness of the surface at the end of emission." If dry at this point, they will presumably continue dry, up to the beginning of the period of compression, and then, mechanical compression alone affecting the fluid, superheating should occur. This was the conclusion of the writer long before the apparatus and method of recent research was ready to give its testimony in the case, as respects economically-operated engines; but the contrary as regards uneconomical engines, in which the working fluid, after entering the cylinder, is very wet. Willans based upon the same conviction the details of design in his engine insuring that the moisture deposited upon the cylinder walls should be swept off as thoroughly as possible by the current of the working fluid. M. Duchesne finds confirmation of these anticipations in the work of Hirn, of Delafond and of Dwelshauvers-Déry, the latter affording him very conclusive evidence, which he reviews at length.

The conclusions reached are the following in substance:

(1) When, in the engine cylinder, the vapor is saturated and the walls humid, the vapor and the water on the surface of the metal assume almost instantaneously the same temperature.

(2) If the surface is dry it may take a temperature superior to that of the fluid.

It is to be remembered that the nearer the working fluid to the state of saturation the more readily does it surrender heat.

In the indicator diagram it is often observed that there exists a point of inflexion at the summit of the compression curve. This has been by earlier authorities generally ascribed to leakage past the piston on attaining a certain limiting pressure at which the piston rings yield. Later observers have suspected, and the writer has long believed, that this peculiar inflexion may mark a point at which the surrender of heat of compression to the metal of the cylinder wall occurs so rapidly, as a consequence of the increasing temperature head, as to cause more rapid con-

densation than can be counteracted in its effect upon pressure by the constantly diminishing rate of compression. This phenomenon in such case is an indication, if not a measure, of the heat exchange thus taking place. M. Duchesne finds confirmation, in his own experiments, of this latter idea, and of the propositions which he has advanced, as well as of the accuracy of the work of M. Dwelshauvers-Déry. — R. H. Thurston in "Science."

MISCELLANEOUS.

RAPID COALING ON THE *IOWA*.—On December 11, 1899, the *Iowa* was coaled at San Francisco in a remarkably short time. Coal was delivered from lighters alongside, and "all hands" on board ship lent simultaneously their efforts to receive and stow it. The work was carried on by the several divisions with a cheerful rivalry which resulted in stowing 1,004 tons in 11 hours and 25 minutes. For three hours of this time the rate was 131¼ tons per hour.

THE NEW KAISER DRY DOCK at Bremerhaven, is the first German dry dock built entirely of stone, and is not only the largest dry dock in Germany, but one of the largest in the world. It is 722 feet in length, 90½ feet in breadth and 31 feet deep. The closing of this dock is accomplished by means of a lifting pontoon, which can be removed from the outer end of the dock to a point some distance inside, when it is desired to dock a small vessel. The dock can be emptied in from 2 to 2½ hours. On either side of the dock are two cranes of 50 tons capacity, and at the southeast corner is a crane with a lifting capacity of 150 tons.—"The Engineer."

END PRESSURE ON DRILLS.—The "American Machinist" reprints some interesting figures obtained some years since by Professor Breckenridge which show the end pressure on twist drills, when working in moderately hard cast steel. The drilling-machine table was supported on the ram of a hydraulic press, and

a steam-engine indicator was used to record the pressure on the latter. It was found that the pressure needed was highest at the start, and diminished when the drill had fairly entered the metal. The following observations were made:

Diameter of drill, inches.	Maximum pressure at starting.	Maximum pressure while drilling, full diameter.
¼	400 pounds.	350 pounds to 400 pounds.
½	900 "	800 " 900 "
¾	1,100 "	800 " 900 "
1	1,450 "	1,000 " 1,150 "
1¼	1,800 "	1,000 " 1,150 "

It would seem that the outer portions of the drill tend to feed the latter in, the end pressure needed being due entirely to the resistance of the more central portions of the drill.

HIGH EXPLOSIVES.—Some experiments were carried out on the 4th of December last, at Crayforness, by the New Explosives Company, Limited, of Stowmarket, for and on behalf of the Sims-Dudley Defence Company of New York, the inventors and proprietors of the dynamite field gun, the object being to ascertain the relative merits of (*a*) explosive gelatine as hitherto employed as the bursting charge for the shell of this gun, and (*b*) high-density gun cotton, as recommended by the Stowmarket Company as a safer and more effective explosive. The experiments resulted entirely in favor of wet gun cotton having a dry gun-cotton primer, the fragmentation of the shell, and the craters made in the ground following the explosion, comparing more than favorably with the effects produced by the explosive gelatine charge.—"Engineering."

A MEGAPHONE WITH A SIREN WHISTLE is being experimented with by the United States Lighthouse Board at the Falkner's Island lighthouse station. This megaphone is 17 feet long and 7 feet in diameter at the mouth, and stands upon a circular platform 28 feet in diameter, upon which it revolves. When the tube is due north of any vessel the ship will hear the north signal—a short, a long and a short blast. If it is due west of a

ship the vessel will hear three short blasts, and so on, with a different combination of long and short blasts for each of the eight points of the compass. The signals are fifteen seconds apart and the apparatus makes a complete revolution in two minutes. All the sounds indicating the various directions are regularly classified, the western being longer than the eastern signals, and those indicating south being shorter than those for signaling north. Recent experiments in sea signaling, it is stated, have proved that it is possible to confine a sound even so powerful as that of a siren, and to project it into space in a given direction, with the same certainty and accuracy that the rays of a searchlight can be projected. On the other hand, sounds sent at an angle of 45 degrees may be absolutely inaudible at all distances beyond a mile, and even at half a mile the closest attention may be required to hear them at all. Direct rays of sound properly focused, as they are in a powerful megaphone, can be heard at a distance of eight or ten miles.—"Engineering News."

FIRE-PROOFING WOOD FOR SHIPS.—The wood which is to be treated is loaded upon small trucks until it conforms approximately to the curve and diameter of the cylinders, care being taken to observe a somewhat uniform spacing, in order to allow a free circulation for the chemical solution with which the wood is to be treated. The timber is then secured to the trucks by iron bands and the trucks are wheeled into the cylinders and clamped down securely to the track. The end doors are then packed with a rubber gasket, swung to, and securely clamped. Steam is now admitted at a pressure of 10 pounds, and the whole charge is submitted to a steam bath, which penetrates the wood, softening and loosening the dried juices which have remained in its fiber. The length of time depends both upon the variety of the wood and its thickness, and it may be anywhere from one to fifty hours. After the steaming process is complete, a powerful vacuum pump is applied for a period of from three to fifteen hours, the vacuum as recorded by the gage being from 27½ to 28 inches. The immediate effect of the vacuum is to draw out of the cellu-

lar structure of the wood all of the saps, juices, etc., and leave it in a condition which might be described as that of an extremely finely divided honeycomb. When the vacuum treatment is complete, an alkaline solution is allowed to flow into the cylinders, great care being taken to prevent the entrance of any air. As the solution rises in the cylinders it is absorbed by the cavities of the wood until the latter is nearly saturated. To assist the absorption, the pressure pump is started and the pressure is raised to 200 pounds, the pumping being maintained as long as there are any indications that the wood is absorbing the solution. The surplus is then pumped back from the cylinders to the storage tank, the doors are opened, and the wood is run out again to be stacked in the air for drying, or, if so desired, it is run directly into a drying kiln. In drying, the water evaporates and leaves all the inner walls of the cells covered with minute crystals of fire-proofing salts.

This completes the process, and the treated wood is to all appearances the same as before it went through the operation. It contains all of its original properties, except that by withdrawing all that remained of the juices the wood has been relieved of that portion of it that would tend to set up fermentation. Hence, incidentally, the treatment is a preservative one, for it substitutes an antiseptic in place of material which is the direct cause of dry rot. The treatment also has the advantage that the wood has been so thoroughly filled that when it comes to be painted very much less oil is required than would be necessary in the case of untreated wood. Moreover, the fireproofed material is susceptible of a much higher polish, even in the case of such soft woods as white pine and poplar.

Extensive tests of the treated timber have shown that the strength of the wood is slightly increased in some varieties and slightly decreased in others, the average decrease of strength in all the varieties of timber that have been treated and tested being not over 5 per cent. Such a heavy impregnation with salts necessarily adds to the weight of timber, the increase being from 5 to 15 per cent., according to the variety that is under treatment.

The average citizen coming into possession of a piece of fireproofed wood would be disappointed at first. He would put it in contact with flame, and would expect that it would show no more effect of the heat than a stone. As a matter of fact, the fireproof wood will char, and if you take a thin shaving of it and subject it to flame you find it will glow so long as the flame is kept applied. Withdraw the flame, and the glow at once disappears. This means that if you want to burn up a piece of the fireproof wood you must keep the flame constantly applied, allowing the charred surface to fall away, when the flame will make a new charred surface. This is the only way you can burn the fireproof wood made at a Newark plant. The heat does not penetrate the wood. The heat, in other words, is not cumulative. For instance, if you dropped a pan of red hot coals on a fireproof floor, and then went away and left them there, the coals would simply eat a hole through the floor and leave a charred rim around the hole. If the floor was of considerable thickness it is certain the coals would die out before the floor was eaten through.—"Marine Review."

East River Bridge Cables.—Specifications have been issued for the cables required for the great suspension bridge over the East River, New York. There will be four cables, each consisting of 37 strands of No. 8 steel wire, each strand to contain 281 wires laid straight. In building, each strand will be held together by temporary bands of wire, which will afterward be removed, and the whole set clamped into one cylindrical cable by steel bands, to which the suspenders will be attached. To protect the cable from wet, and consequent corrosion, it will be covered between the suspension pieces by thin steel plating. The steel to be used is an open-hearth steel, having not more than 0.03 per cent. of sulphur nor more than 0.04 per cent. of phosphorus, and the wires, after drawing, are to show a tensile strength of not less than 200,000 pounds per square inch, with an elongation of 5 per cent. in 8 inches, and the wires must be capable of coiling cold round a rod of their own diameter. The wire is to be in lengths of not less than 4,000 feet.—"Engineering."

WASTE GASES FROM COKE OVENS.—An interesting experiment is now being tried at Boston, Massachusetts, where a company are establishing coke ovens with the intention of distributing the waste gases for lighting and fuel purposes. About 400 ovens have now been erected, but the plant is finally intended to include 800 more, or 1,200 in all. These ovens are of the Otto-Hoffman type, and have a capacity of 6 tons of coal each. It is further intended to collect and utilize the by-products; and by some means, not yet disclosed, the poorer gases given off during the distillation are to be separated from the richer. The former will be largely utilized at the works, whilst the richer are to be distributed to the city.

NEW STEEL FOUNDRY.—A steel foundry is the latest venture of the Westinghouse Company. The works are to be situated at East Pittsburg, and will cost more than $1,000,000. The Westinghouse companies will thus still further diminish their dependence on outside firms. Both open-hearth castings and ingots are to made, the latter being intended for forgings. Hammers and forging presses capable of turning out 20-ton forgings are to be laid down.

JAPANESE SHIPBUILDING.—A Japanese shipbuilding firm has just turned out a 12,000-ton steel twin-screw steamer, the *Awa Maru*, which, according to United States Consul Harris, at Nagasaki, who reports the fact to the State Department, is equal in every respect, including cabin accommodations, to the best class of Atlantic steamships. Material has been ordered for two other steamers of the same kind for the same line, and two are under construction for another line. The shipbuilding industry in Japan appears to be flourishing, with every likelihood of it continuing so.—"Marine Record."

COOLING ROLLED BARS.—In certain of the newer American rolling mills the bars are rolled in lengths of 300 feet and allowed to cool on a special cooling bed which keeps them straight. The great length of the bars renders very evident

certain peculiarities in their contraction when cooling, the total movement being between three inches and four inches. It is noted that when first placed on the bed contraction proceeds rapidly, then checks, and finally ceases. The bar then expands again, probably during recalescence, after which contraction proceeds uniformly till the metal is cold.—"Engineering."

PORTLAND CEMENT TESTS.—The following regulations governing the acceptance of Portland cement are in use in Holland. The cement must not leave more than 10 per cent. on a seive of 900 meshes per square centimeter (5,800 per square inch). Setting, which should take at least two hours, is tested by filling an ebonite ring 40 centimeters (1.57 inches) high with the mortar to be tested. A needle of 1 square millimeter in section, loaded with 300 grammes is applied to the mortar, and the setting ts held to commence when this rod fails to penetrate to the bottom of the mortar, and to finish when it fails to indent the surface. The test for constancy of volume is performed by placing a cake of cement on glass and protecting it from drying for 24 hours. This cake should not crack or change shape even after prolonged storage. The tensile tests are made on blocks of at least 5 square centimeters (.775 square inch) section, and the specimens are prepared with 1 part by weight of cement, 1 part by weight of normal sand, and 0.3—0.4 parts of water. After storage for 24 hours after making in moist air, followed by 27 days in water, these specimens should show a tensile strength of at least 227 pounds per square inch. Compression tests made from the same mixture, the blocks being 2-inch cubes, should fail at a load equal to not less than 2,275 pounds per square inch. If seven-day tests are used, the tensile strength should be 142 pounds, and the crushing load 1,422 pounds per square inch. Specimens of neat cement are required to show a tensile strength in a seven-day test of 355 pounds per square inch, and in a 28-day test a strength of 498 pounds per square inch.—"Engineering."

TUNGSTEN AND MOLYBDENUM STEELS.—The following communication, by Mr. R. Helmhacker, in a late issue of the "Engi-

neering and Mining Journal," relative to the peculiarities of tungsten and molybdenum steels, is interesting:

Steel alloyed with a small proportion of tungsten has been used for some years in the manufacture of tools and other articles requiring a hard and tough metal. Some years ago Prof. V. Leepin, of St. Petersburg, Russia, suggested that molybdenum might be used for the same purpose, as it strongly resembles tungsten in its properties. After some discussion he succeeded in having molybdenum-steel made at the Pubilov Iron Works, and carried on a number of tests, the results of which were published in the Russian "Mining Journal" for 1897. In making these tests great pains were taken to have the steel, both tungsten and molybdenum, made under the same conditions. Both steels were made in Siemens regenerative furnaces from a charge consisting for the molybdenum-steel of 20.6 kilograms of basic open-hearth steel, 2 kilograms Swedish charcoal pig iron, 2.3 kilograms Swedish charcoal blooms, 0.1 kilogram ferro-silicon and 1 kilogram molybdenum in a metallic form, but combined with a small quantity of carbon. For the tungsten-steel the charge consisted of 16 kilograms basic open-hearth steel, 3.7 kilograms Swedish pig iron, 2.9 kilograms Swedish charcoal blooms, 0.1 kilograms ferro-silicon and 1.8 kilograms ferro-tungsten having 48 per cent. tungsten. Both steels were cast into ingots, which were afterwards rolled into rods of a suitable size for the testing machine. By analysis the percentage of tungsten was found to be 3.8, and that of molybdenum 3.7.

The experiment showed that the molybdenum-steel is somewhat softer than the tungsten-steel. Oil tempering and high heating after hardening increased the limit of elasticity in the molybdenum-steel. Common tempering in oil has a greater influence on the tungsten-steel than on the molybdenum, but, on the other hand, the molybdenum-steel was stronger than the tungsten after heating and hardening in water. Tungsten-steel was more apt to split than the other when worked, and broke sooner when bent cold.

In many respects the properties of the two kinds of steel

were very similar, but the molybdenum-steel seems to stand forging and hardening better, showing that in some cases it may furnish a better metal than the tungsten-steel.

We have heretofore referred to the use of molybdenum, tungsten and some other of the rarer metals in the processes for making armor plate at the Krupp works in Germany and the Creusot works in France. At both these establishments the alloys used are kept secret, but it is probable that a mixture of several of the rarer metals is used, including both tungsten and molybdenum.

ELECTRICITY ON BOARD SHIP.—The constant increase of the use of electricity on board ship is very clearly shown in the following table, taken from the report of the Bureau of Equipment:

Name of ship.	Kilowatts.	Horsepower.
Indiana,	72	96.5
Massachusetts,	72	96.5
Oregon,	72	96.5
Iowa,	96	115
Kearsarge,	350	480
Kentucky,	350	480
Alabama,	256	343
Wisconsin,	256	343
Illinois,	256	343
Maine,	328	454.5
Ohio,	328	454.5
Missouri,	328	454.5

THE STUDY OF FUELS BY X-RAYS.—Although the earliest practical applications of Professor Roentgen's discovery were in the domain of surgery, other uses outside of the physical laboratory are gradually being developed.

Among these is the application of radiography to the examination of coals, and from an article by Herr F. Kotte in "Stahl und Eisen" the following abstract is made:

It is well known that the rays do not pass through all materials with equal facility, and that there are some substances which

offer a marked opacity to them. Both wood and crystallized carbon in the form of diamond, are practically transparent to the X-rays, and, as might be expected, the various forms of carbonized wood are also readily traversed. When, in addition it is understood that the usual impurities in coal, such as slate and pyrites, are practically opaque to the rays, it will be seen that radiography offers a means of detecting the non-combustible in a piece of coal without necessity of the destruction of the specimen.

Herr Kotte refers to the earliest researches in this line of investigation by Dr. Thorner in 1897, but the latest work in this line has been done by Professor Couriot at the Ecole Centrale, in Paris, and the radiographs made by the latter of specimens of peat, lignite and various kinds of soft and hard coal show very clearly the manner in which the presence of slate and other impurities can be determined.

Examinations of pieces in the lump can only be of a qualitative character, but a method devised by the author and by Dr. Aulich enables quantitative results to be obtained. For this purpose the sample must be ground to powder and a layer of standard thickness examined by X-rays in comparison with a standard scale of comparison. The degree of opacity may then be made a measure of the impurity, and while the exact nature of the impurity cannot be obtained, the percentage of noncombustible can be measured with some degree of accuracy, although the method can only be regarded as an approximate one at the present time.

Herr Kotte's paper is accompanied with excellent reproductions of radiographs of various specimens, and further study in the application of the method may result in a greater degree of precision in its use.

DIFFICULTIES IN FLOATING THE *PARIS*.—Additional details which are gradually made public regarding the work of floating the American liner *Paris*, off the Manacles on the coast of Cornwall, serve to emphasize the difficulty of the undertaking which was successfully carried out by the Nordische Bergungs-Verein,

of Hamburg, after leading English firms had abandoned the task. The *Paris* went ashore May 21st, and the three large wrecking boats of the German corporation did not make their appearance at the scene until June 7th. Just thirty-three days were consumed in the patching, blasting and pumping necessary for the removal of the rocks which held the vessel. The German divers first made a survey of the vessel's bottom and found that great pinnacles of granite had penetrated her outer shell about midships, under the first and second boiler rooms and No. 5 hold. She rested, as it were, upon a great pivot. The work of the divers was seriously impeded by seaweed as thick as jungle grass and 10 feet high, and the removal of this was the first task undertaken. Later it was towed to a point where the tide caught it and carried it out.

The Germans early decided to abandon the idea of the English wreckers, which had been to lift the vessel off the rocks by means of pontoons and bags inflated with air and placed under the keel. Instead they adopted the plan of blasting away the teeth of granite which held the liner. Before this could be undertaken, however, it was necessary to do an immense amount of patching from the bow aft to the midship section, and the steamer's bow was lifted out of the water by adding weight to her stern and filling her after compartments with water. Only small blasts were used for fear of injuring the steamer, but in all more than 15,000 cubic feet of rock were removed, and it was, moreover, all done under water. As the boulders were torn up, hawsers were made fast to them by the divers and the wrecking steamers dragged them out of the way.

The greatest difficulty which the salvers experienced was when, after a month of work, they were finally ready to blast away the last pillar of granite which held the *Paris*. It was discovered that the pumps on the stranded steamer had lost suction and would not lower the water in her hold beyond 20 feet, whereas she had been filled flush to her depth of 50 feet in order to raise her bow. Thereupon it was necessary to resort to the especially powerful pumps of the *Berthilde*, one of the wrecking steamers. Holes were cut in the decks and sides of

the *Paris*, and the *Berthilde* lay alongside and sucked the water ballast out at the rate of 4,500 tons an hour. As the steamer righted the weight of the water rushing aft tore out some of the compartments, and the engine rooms were inundated and the furnaces submerged. Portable pumps and boilers then had to be placed on board to work independently of the vessel's own power.

Hardly had the *Paris* been righted and her engine rooms pumped out, when a gale sprang up which opened her seams and allowed her to again fill. To steady her during the storm and keep her from being driven farther on the rocks, anchors were carried out from the bow and stern and both sides and the chain of the anchors kept taut by steam winches on the vessel's deck. When the gale subsided, the *Paris* had to be pumped out again and some more patching done. The patches utilized were formed of shields of wood fitted over the breaks and padded around with canvas and rubber. Some of these shields were as large as the door of a house, but the actual holes in the *Paris* were not so large as might be imagined, the largest being only about four feet square. Plates had been strained and rivets started all along her bottom, however. The actual floating of the vessel was accomplished by setting in motion the steam winches connected with the chains of the stern anchors, while the three wrecking steamers united simultaneously in a long, steady pull.—"Marine Review."

SHIPS.

UNITED STATES.

New Ships.—Recommendations of the Secretary of the Navy, in his last annual report as to new ships, were as follows: First, three armored cruisers of about 13,000 tons trial displacement, of a maximum draught at deep-water load not to exceed 26 feet, carrying the heaviest armor and most powerful ordnance for vessels of their class, to be sheathed and coppered and to have the highest practicable speed and great radius of action; second, twelve gunboats of about 900 tons displacement, to be sheathed and coppered; and third, as recommended a year ago, three protected cruisers of about 8,000 tons trial displacement, carrying the most powerful ordnance for vessels of their class, to be sheathed and coppered, and to have the highest practicable speed and great radius of action. It is also recommended that if any of the foregoing vessels are authorized, the law should provide that in case satisfactory bids can not be obtained for their construction by contract, the Department shall have authority to construct the same in the Navy Yards. In support of this proposed further increase of ships the Secretary presents the following tables as showing what other great powers are doing, and from which it appears that only Italy and Japan laid down less tonnage than this country during 1899, and that Italy alone has less tonnage under construction:

LAID DOWN IN 1899.

Nation.	Battleships.	Cruisers.	Torpedo vessels.	Total.
	tons.	*tons.*	*tons.*	*tons.*
England	116,000	127,700	4,200	247,900
France	25,456	113,943	4,800	144,199
Germany	44,324	2,800	4,200	51,324
Italy	32,000	.....	1,800	33,800
Japan*	.....	.....	.....	.....
Russia	57,426	6,375	1,700	65,501
United States	36,970	†	4,191	.....
Monitors	12,940	.....	.....	54,101

*All vessels called for by Japan's first building programme are either completed or under way.
†In November, 1899, bids were received for six protected cruisers of 3,200 tons.

TOTAL NOW UNDER CONSTRUCTION.

Nation.	Battleships.	Cruisers.	Torpedo vessels.	Total.
	tons.	*tons.*	*tons.*	*tons.*
England	251,700	267,080	*12,900	531,680
France	80,281	166,283	8,969	255,533
Germany	99,729	41,851	6,655	148,235
Italy	78,454	38,901	3,185	120,540
Japan	59,700	63,280	7,133	130,113
Russia	115,713	92,697	16,566	222,976
United States	94,715	4,935	10,646	.....
Monitors	12,940	.....	.....	123,236

*Approximate.

Georgia Class.—The three battleships authorized by Act of March 3, 1899, will be named *Georgia*, *New Jersey* and *Pennsylvania*.

But little actual progress has been made on the designs of these vessels owing to the restriction contained in the act forbidding contract being made for their hulls until contracts had been made for the armor at a price not exceeding $300 per ton. The principal features of the designs, however, have been agreed upon by the Board of Construction, and these contemplate a displacement of about 14,000 tons, and a speed of not less than 19 knots per hour, while a large radius of action is provided for by a bunker capacity of 2,000 tons of coal.

The armament of these ships as proposed will include two turrets of the double or super-imposed type, now believed to be of undoubted superiority to the single type. These turrets will be located one forward and the other aft, and will contain two 12-inch guns in each lower turret, and two 8-inch guns in each upper turret, all of the latest design and contemplating the use of smokeless powder.

Besides these guns, the main battery will consist of twelve 6-inch, rapid-fire guns in broadside.

The question of sheathing is still under discussion, or at least not finally adopted.

Owing to the fact that the Chief Naval Constructor has not as yet made sufficient progress with the actual plans to determine the proper arrangement of the weights, the precise distribution

of the armor has not been decided. As the weight of the armor for these ships was a very large item, the adoption of the question of the Krupp or the Harveyized material was extremely important. The adoption of the material treated by the Krupp process means that 1,000 tons of weight will be available for distribution among other vital characteristics of the ships.

It is estimated that the total cost of the new vessels when ready for sea will be about $7,000,000 each. They will cruise 7,000 miles straightaway, and there will not be three ships of similar fighting power in any navy in the world.

New Armored Cruisers.—The three armored cruisers authorized by the act of March 3, 1899, will be named the *California*, *Nebraska* and *West Virginia*. They are to be of about 12,000-tons trial displacement, and will be probably the most powerful vessels of their class afloat.

No details have yet been completed regarding these vessels, progress being delayed by the armor limitation of the act, as in the case of the battleships.

U. S. S. Kearsarge.—This new battleship was placed in commission on Tuesday, February 20, 1900, at the works of the builders, the Newport News Ship and Dry Dock Company.

U. S. S. Albany.—The contract trials of the machinery of this vessel, building at the works of R. & W. Harthorne, Leslie & Co., Newcastle on Tyne, England, took place during January, 1900, and were satisfactory in every respect.

The first trial was the four runs on the measured mile at maximum speed called for by the contract of 20 knots, and took place on January 9th, off the mouth of the Tyne. The mean results of the performance of the machinery during these runs were as follows:

Steam pressure at the boilers, pounds	147
Air pressure in fire rooms, inches	1.35
Revolutions of the fire room blowers, per minute	382
Pressure at the engines, port, pounds	141
starboard, pounds	140.5
I.H.P., port	3,545
starboard	3,538
total, both engines	7,083

Vacuum, port, inches	24.7
starboard, inches	27
Revolutions, port	164
starboard	158.8
Speed, knots per hour	20.51
Mean displacement, tons	3,446

The speed maintained on these trials was thus 0.51 of a knot in excess of that called for in the contract.

The required six-hour trial was made on January 11, 1900, beginning at 10·05 A. M. and ending at 4·05 P. M. The following are the mean results of the performance of the machinery during this trial:

Steam pressure at boilers, pounds	148.5
Air pressure in fire rooms, inches	.235
Revolutions of the fire room blowers	174
Pressure at engines, port, pounds	129
starbord, pounds	131
I.H.P., port	2,638
starboard	2,696
total, both engines	5,334
Vacuum, port, inches	25.9
starboard	27.8
Revolutions, port	150.6
starboard	148.2
Speed, mean, by revolutions, knots	19.52
Displacement, tons	3,446

A more complete description of these contract trials, with details of machinery and ship data, will be published in the next issue of the JOURNAL.

U. S. S. Hartford.—Dock trials of the new machinery of this historic vessel were made on January 3 and January 6, 1900.

Owing to the orders concerning the departure of the vessel these trials could not be extended as far as desirable, but the engines were run long enough to demonstrate their safe condition and readiness for service. Some slight defects were developed which were remedied without difficulty.

U. S. S. Atlanta.—A dock trial of the new machinery of this vessel was held at the New York Navy Yard on December 2, 1899. The first trial during the forenoon of that day was had

with natural draft. It was found possible to secure, under these conditions, slightly more than 45 revolutions. At 1·30 P. M., the fire rooms were closed and the trial made under forced draft. No air-pressure gages were fitted, but the blowers were run at an average of about 500 revolutions per minute. Under the conditions of the trial, and owing to the inexperience of the firemen, the highest speed capable of being continuously maintained was between 55 and 60 revolutions.

From data taken during the period of best performance, the following results are deduced: Boiler pressure, 160 pounds; revolutions per minute, 75; I.H.P., H.P. cylinder, 925.35; I.P. cylinder, 775.51; L.P. cylinder, 892.96; total H.P., 2,593.82.

Generally speaking, however, the boilers worked well in all respects, and the engines performed in a satisfactory manner.

The Armor Question.—The Secretary of the Navy thus presents the armor situation at the close of 1899: All the armor for the battleships *Kearsarge* and *Kentucky* has been contracted for and delivered. All the armor for the battleships *Alabama*, *Illinois* and *Wisconsin* has been contracted for, and deliveries under the contracts will probably be completed by May, 1900. The armor for the five vessels above named was contracted for at $400 per ton, exclusive of a royalty for face hardening, for which $11.20 per ton might, under certain conditions, be paid.

In August and September of the present year contracts were made for 2,152 tons of armor for the four harbor-defense monitors authorized by the act of May 4, 1898. At the same time contracts were made for 116.58 tons of armor for the battleships *Maine*, *Ohio* and *Missouri*, this latter small quantity of armor being necessary in the early stage of interior construction. The above armor for monitors and battleships, aggregating 2,268.58 tons, was contracted for at $400 per ton. All the deliveries will probably be completed by April, 1900.

There remain to be contracted for 7,358 tons of armor for the *Maine*, *Ohio* and *Missouri*. These vessels are now building, and it is imperative that their armor should be contracted for early in the coming year; to delay it beyond that time will in all probability delay the completion of the vessels beyond the contract date of completion. Under existing laws $400 a ton may

be paid for armor "of a suitable quality" for these vessels; but $400 a ton will not apparently buy the best armor, which for such vessels is, of course, the only "suitable" armor.

It will probably buy armor made by the ordinary process of face hardening, which, though good, is not the best, and the Department does not, therefore, consider it suitable for the vessels in question. Armor of this kind was reluctantly ordered for the four new monitors, because the vessels were progressing rapidly and the Department desired to avoid the delays and embarrassment likely to arise if their armor was not forthcoming when required. Moreover, these vessels are of a low freeboard type, and offer comparatively small targets, while the contrary is the case with battleships, whose prestige is very great, and should not, therefore, be impaired by the use of any but the very best armor.

In addition to the 7,358 tons of armor required for the *Maine*, *Ohio* and *Missouri*, there will be required about 9,000 tons for the three battleships and about 5,100 tons for the three armored cruisers authorized by the act of March 3, 1899, a total of about 21,458 tons of armor required in all and not yet contracted for.

Torpedo Boat Somers.—A trial of this vessel has at last been attained over a five-mile course on Long Island Sound, and the results as far as speed under the partial forced draft was about 17½ knots. This is smooth water. A boiler tube burst on the first attempt to reach the course, slightly injuring a machinist and necessitating a return to the yard for a few hours.

The *Somers'* boiler tubes have become unreliable through corrosion during the "troublesome existence" she has led since her purchase, and the necessarily long periods of improper care.

It is possible that the boat will be hauled out and laid up until possible emergencies may call her into service. The immediately necessary work of retubing boilers probably will be taken in hand at once.

A novel feature of this boat is a small bow rudder, which is controlled from the forward conning tower. It houses like a centerboard in its trunk, and is of great value in turning the vessel quickly. Using it, the boat turned about one-third faster than with only the after rudder.

In the trials to determine her tactical diameter, the *Somers*, using only her stern rudder, turned a complete circle in 390 yards. From full speed ahead to a dead stop the unofficial time taken was fifty-nine seconds. Several short loops were made at full speed under port helm, the mean of the time taken being forty seconds.

The *Somers* was built in 1893 for the German Navy by Schichau, at Elbing, Prussia. She was rejected by the Government and purchased for the United States early in 1898. After three unsuccessful attempts to bring her to New York in tow of the cruiser *Topeka*, her crew refrusing to work in the bad weather encountered, war with Spain was declared and she was laid up until April, 1899, when she was brought here on the steamship *Manhattan*.

Sebago.—The name of the United States tug *Takoma* has been changed to *Sebago*, owing to the similarity of the former name to that of the cruiser *Tacoma*.

Sale of Condemned Vessels.—During the year 1899, the following vessels, condemned as unfit for further service and stricken from the Navy Register in pursuance of section 2 of the Act of August 5, 1882 (Stat. L., vol. 22, p. 296), have been appraised and disposed of at public sale in accordance with section 5 of the Act of March 3, 1883 (Stat. L., vol. 22, p. 599), viz:

Name and type of vesssel.	Navy yard at which located.	Appraised value.	Date of sale.	Purchaser.	Price.
			1899.		
Wyandotte, single-turret monitor.	League Island, Pa.	$6,382.50	Jan. 17	Chas. Gibbons Davis, Philadelphia, Pa.	$12,631.52
Comanche, single-turret monitor.	Mare Island, Cal.	1,200.00	Mar. 22	Pantoskey, Bircovich & Livingston, Oakland, Cal.	6,581.25
Governor Russell, ferry boat.	Norfolk, Va.	35,000.00	July 19	City of Boston, Mass.	25,000.00
East Boston, ferry boat.	Boston, Mass.	30,000.00	July 19	Arthur J. Phillips, Harry L. Maynard, Theo. J. Wool and John L. Watson, Portsmouth, Va.	38,091.00
Vulcan, repair ship.	League Island, Pa.	100,000.00	July 19	Michael Jenkins, Baltimore, Md.	175,750.00
Niagara, steamer.	New York.	60,000.00	July 19	Henry P. Booth, New York, N. Y.	75,563.00
Hector, steamer.	Boston, Mass.	50,000.00	Oct. 10	The Metropolitan Coal Co., Boston, Mass.	65,150.00
Ajax, single-turret monitor.	League Island, Pa.	13,000.00	Oct. 10	H. A. Hitner's Sons, Philadelphia, Pa.	29,566.66
Passaic, single-turret monitor.	Pensacola, Fla.	11,000.00	Oct. 10	Frank Samuels, Philadelphia, Pa.	19,785.66

The total sum received from these vessels is $448,119.09, being $141,536.59 in excess of their appraised value, from which $758.96, the cost of publishing the several advertisements inviting proposals for their purchase, was paid. The net proceeds amount to $447,360.13.

The following table shows the vessels loaned to certain of the States for use of naval militia organizations:

Vessels.	State to which loaned.	Date of transfer.
Aileen,	New York,	May 18, 1899.
Dale,	Maryland,	Jan. 3, 1895.
Elfrida,	Connecticut,	Apr. 29, 1899.
Fern,	District of Columbia,	Oct. 22, 1898.
Hornet,	North Carolina,	Dec. 24, 1898.
Huntress,	New Jersey,	Jan. 16, 1899.
Inca,	Massachusetts,	May 27, 1899.
Marion,	California,	Jan. 20, 1898.
Minnesota,	Massachusetts,	Oct. 22, 1895.
New Hampshire,	New York,	Nov. 13, 1894.
Pinta,	California,	Mar. 2, 1898.
Portsmouth,	New Jersey,	June 29, 1895.
St. Louis,	Pennsylvania,	Dec. 6, 1894.
Shearwater,	Pennsylvania,	Dec. 31, 1898.
Stranger,	Louisiana,	Dec. 26, 1898.
Siren,	Virginia,	June 22, 1899.
Sylvia,	Maryland,	Dec. 19, 1898.
Yantic,	Michigan,	Nov. 3, 1897.

T. A. M. Craven.—On December 16, 1899, this torpedo boat made several runs over the measured mile at the Southport, Me., course for the purpose of standardizing the screws, and later in the same day made a run for one hour. These were not acceptance trials.

The weather was bitterly cold during these tests, and the vessel was covered with ice from stem to stern. During the hour's run the average steam pressure in the engine room was 205 pounds, the average vacuum 26 inches and the average number of revolutions 312.775. It was impossible, from the data taken,

to determine with any accuracy the speed made on this one hour's run, but comparing the revolutions made with those obtained during the trial of the *Dahlgren*, her sister ship, it is estimated that the speed was approximately 29.7 knots per hour. The engine proved to be stiff, well balanced and gave very little vibration.

On February 21st a final acceptance trial was obtained, resulting in a speed of slightly over 322 revolutions per minute, corresponding to 30.1 knots per hour.

ENGLAND.

Cressy.—This cruiser was launched December 4 last, and is a sister ship to the *Sutlej*, launched on the 18th of November, from the Clydebank shipyard. She gives name to the particular class of cruiser of which five others are being built—four on the Clyde and two at Barrow. A special feature of the vessel is that extending from where the main broadside 6-inch armor terminates to the vessel's extremities is 2-inch nickel-steel armor plating. This specially-hardened nickel-steel armor has been made by William Beardmore and Co., of Parkhead Forge and Steel Works. The *Cressy* is the first British naval vessel in which the Parkhead plating has been worked so extensively into the regular armor-plating scheme of the hull.

The *Cressy*, like the *Sutlej*, is to develop on trial 21,000 indicated horsepower, estimated to propel the vessel at 21 knots. The propelling machinery consists of two sets of triple-expansion engines fitted in two watertight compartments, each set having four inverted cylinders, working on four cranks. The high-pressure cylinder is 36 inches diameter, the intermediate 59 inches, and each of the low-pressure 68 inches diameter, the stroke in all cases being 48 inches. The high and intermediate-pressure cylinders are each fitted with a piston valve, and each low-pressure cylinder with a double-ported slide valve with a relieving ring at the back; all the valves being worked by the usual double-eccentric and link-motion gear. The reversing is effected by means of double-cylinder steam engines, with gear of the all-round type. Hand gear is also fitted. The crank,

thrust and propeller shafting is of forged steel and hollow, supplied by the Parkhead Company. The propeller bosses are of gun metal, fitted with four adjustable blades of manganese-bronze. The main condensers are at the backs of the engines, and are cast of brass of oval form, fitted with brass tubes, the condensing water being supplied by four centrifugal pumps of gun metal, each fitted with independent engines. The feed, bilge and hotwell engines are all independent, and separate from the main engines; steam for these and all other auxiliary machinery being supplied by a special range of steam pipes. The exhaust steam will be arranged to discharge to the auxiliary condensers, the atmosphere and the low-pressure receivers. There are two auxiliary condensers, each fitted with a circulating pump and a small air pump.

The vessel will be fitted with the usual auxiliary machinery, viz: a complete distilling plant to supply fresh water to the boilers and also for drinking purposes, three sets of engines and dynamos for producing the necessary current for electric lighting, two double-cylinder direct-acting engines, with the necessary gear for steering purposes; two complete sets of air-compressing engines and pumps, with the air reservoirs for charging torpedoes, and two vertical refrigerating machines of the cold-air type, with the necessary cold chamber for ship's provisions. Steam will be supplied by an installation of thirty water-tube boilers having economizers, all of the latest Belleville type. The boilers are arranged in four groups, each group fitted in a water-tight compartment. They are designed to work at a pressure of 300 pounds, valves being fitted to reduce the pressure to 250 pounds at engines. Pumping engines are fitted in each stokehold to supply air to the furnaces and combustion chambers, and the necessary air for the stokehold ventilation will be supplied by laage fans, as also for the engine room and ship ventilation.—"The Engineer."

Steam Trials.—The following *résumé* of the results of the trials of the new first-class battleship *Ocean* are of interest, although the first two of these trials have been already referred to in the JOURNAL. The sea trials specified were three in number, viz: Thirty hours at about 2,700 I.H.P.; thirty hours at about

10,250 I.H.P.; eight hours at full 13,500 I.H.P. All these were completed to the satisfaction of the Admiralty inspecting officers. The last of the series, viz: the eight hours' full-power trial, took place on 30th October last, when a mean I.H.P. of 13,828 was obtained with 113 revolutions per minute. The whole of the machinery worked well and gave no trouble.

.....	Average of 30 hours, 27th and 28th July.	Average of 30 hours, 2d and 3d August.	Average of 8 hours, 20th Oct., 1899.
Air pressure	Fans not working.	Fans running 130 revs. No. air pressure.	Fans running 177 revs. Air pressure .07
Vacuum:			
Port	27.5	26.2	27
Starboard	27.8	27.0	27
Steam pressure in stokehold	210	267	272
Steam pressure in engine-room	184	221	233
Revolutions:			
Port	67	103.1	114.5
Starboard	66.6	101.9	111.1
Receiver pressure:			
H.P., port	165.3	221	228
starboard	167	216	224
I.P., port	26.2	52	78
starboard	26.2	54	71
L.P., port	14.1	5.9	14
starboard	13.6	9.8	12
Indicated horse power:			
H.P., port	466	1,862	2,170
starboard	506	1,854	2,019
I.P., port	501	1,763	2,442
starboard	527	1,776	2,501
L.P., port	369	1,459	2,306
starboard	398	1,600	2,390
Total	2,767	10,314	13,828
Speed	11.4*	16.2*	18.74†
Number of boilers in use	8	20	20
Coal consumption per I.H.P., pounds	1.84	1.63	1.76

*Approximate. Ship foul. †Ship clean.

Viper.—The turbine destroyer *Viper* for the English Government went out again on the mile January 8, and the results were more than satisfactory. The turbines have been changed since the first trial, and at this time their performance was excellent.

Several runs were made at about 33 knots, and then, on a spurt, four runs were made at an average of 34.8, and then two runs at an average of 35.2 knots.

The only thing that gave any trouble were the air pumps, which were inclined to stop. The turbines ran very quietly, the only place on the boat where there was any noise of any amount was in the after part or ward room, which is over the screws; here the noise was very great, and it was attributed to cavitation at the propellers.

H. M. Torpedo-boat Destroyer Spiteful, built and engined by Palmer's Shipbuilding and Iron Company, Limited, Jarrow-on-Tyne, has just completed her official trials at Portsmouth. The first trial was stipulated to be at a speed of about 29¾ to 30 knots per hour for three hours, to test the consumption, which was not to exceed 2½ pounds per indicated horsepower. It was found that at 29.9 knots per hour the consumption was at the low rate of 2.3 pounds per indicated horsepower. On the second trial the vessel was to be driven at not less than 30 knots per hour during three consecutive hours, but at the same time it was desired to keep the speed as little in excess of the 30 knots as possible. On six runs over the mile the speed was easily maintained at 30.371 knots per hour, and the engines were then adjusted so that the average of the three hours came out 30.06 knots per hour. On the final or 12 hours' trial the vessel was to be run at a speed of 13 knots per hour, and the consumption measured. The average speed was 13.05 knots per hour, the power 450 indicated horsepower, and the consumption at the rate of 1.5 pounds per indicated horsepower per hour, so that the coal she is capable of stowing would enable the vessel to steam about 4,000 sea miles. This consumption is considered very low, and is believed to be a record performance for a vessel of her displacement. The whole of the trials were gone through in a very comfortable manner, entire absence of vibration, ample and economical supply of steam. This is the fiftieth vessel and the twelfth destroyer delivered to Her Majesty's government by her builders. She is generally similar to the other 30-knot boats by Palmers, and has two sets of triple-expansion engines, and four Reed's patent water-tube boilers, working at 250 pounds pressure and 6,300 indicated horsepower. Messrs. Palmers have three more destroyers in hand.

RESULTS OF OFFICIAL STEAM TRIALS MADE DURING 1899 BY BRITISH WARSHIPS.

Name of ship.	Type.	Builders of ship.	Constructors of machinery.	Thirty hours' coal-consumption trial.			Thirty hours' coal-consumption trial at higher powers.			Full-power trial.		
				I.H.P.	Speed.	Coal per horse-power hour.	I.H.P.	Speed.	Coal per horse-power hour.	I.H.P.	Speed.	Coal per horse-power hour.
					knots.	*pounds.*		*knots.*	*pounds.*		*knots.*	*pounds.*
Canopus.....	First-class battleship.	Portsmouth Yard.	Greenock Foundry Co.	2,813	11.3	1.82	10,457	17.2	1.68	13,780	18.5	1.72
Ocean.....	do.	Devonport Yard.	Hawthorn, Leslie & Co.	2,767	11.4	1.84	10,314	16.2	1.63	13,828	18.74	1.76
Goliath.....	do.	Chatham Yard.	John Penn & Co.	2,807	11.7	1.73	10,413	17.1	1.54	13,918	18.4	1.91
Amphitrite...	First-class cruiser.	Vickers, Son and Maxim.	Vickers, Son and Maxim.	3,751	12.8	1.54	13,695	19.52	1.43	18,229	20.94	1.57
Ariadne.....	do.	J. Brown & Co.	J. Brown & Co.	3,754	13.3	2.05	14,049	20.1	1.73	19,156	21.5	1.66
Gladiator....	Second-class cruiser.	Portsmouth Yard.	Maudslay, Sons and Field.	2,162	11.8	2.16	7,154	17.5	1.99	10,120	19.1	2.31
Hermes.....	do.	Fairfield Company.	Fairfield Company.	2,151	13.4	1.78	7,705	18.8	1.57	10,264	20.5	1.58
Highflyer....	do.	do.	do.	2,135	12.5	1.63	7,644	19.4	1.49	10,344	20.1	1.407
Hyacinth.....	do.	London and Glasgow Shipbuilding Co.	London and Glasgow Co	2,135	12.1	1.73	7,718	17.34	1.47	10,536	19.4	1.58
Perseus.....	Third-class cruiser.	Earle's Co.	Earle's Co.	*3,627	*17.2	*2.1	*5,243	*18.9	*2.26	7,065	20.0	.....
Pyramus.....	do.	Palmer's Co.	Palmer's Co.	3,605	17.49	2.05	5,424	19.9	.....	7,303	20.7	.....
Pioneer.....	do.	Chatham Yard.	Fairfield Company.	3,665	16.3	2.2	5,263	17.7	.....	7,185	19.75	.....
Pomone.....	do.	Sheerness Yard.	J. Penn & Co.	3,600	16.5	2.44	5,523	20.2	.....	7,314	20.8	2.45
Prometheus..	do.	Earle's Co.	Earle's Co.	3,572	17.5	2.01	5,187	19.8	2.3	7,258	20.8	.....
Psyche.....	do.	Devonport Yard.	Devonport Yard.	3,646	16.8	2.301	5,098	19.3	2.44	7,031	20.48	.....
Dwarf.....	First class gunboat.	London and Glasgow Co.	London and Glasgow Co.	687	11.6	2.22	966	13.1	.....	1,401	14.15	2.46
Thistle.....	do.	do.	do.	696	11.5	2.13	966	12.93	2.09	1,352	13.94	2.47
Bramble.....	do.	Potter & Co.	Fawcett, Preston and Co.	661	10.85	2.32	940	11.1	2.4	1,360	13.38	2.6
							8 hours' N.-D. trial.			3-hours' F. P. trial.		
Seagull†.....	Torpedo gunboat.	Chatham Yard.	Maudslay.	.....	.....	.....	2,659	17.33	1.74	3,546	19.0	2.3
							30-hours' trial.					
Skipjack‡....	do.	do.	Palmer's Co.	.....	.....	.....	1,222	14.4	1 6	6,089	20.258	.....
							8-hours' trial.					
Barham†.....	Third-class cruiser.	Portsmouth Yard.	Hawthorn, Leslie & Co.	.....	.....	.....	4,500	18.6	.....	6,152	M. M.	.....
Belloma†.....	do.	Hawthorn, Leslie & Co.	do.	.....	.....	.....	4,250	19.1	.....	6,035	19.75	.....

* These trials made at end of 1898 subsequent to the publication of our table a year ago. † These trials after ships had been reboilered.
‡ This trial after new engines and boilers had been fitted.

The first nine vessels—to the *Hyacinth*—have Belleville boilers, although the steam generators of the *Gladiator* are not of the economizer type. The Yarrow boiler is fitted to the *Dwarf*, *Thistle* and *Bramble*, the Thornycroft to the *Perseus*, *Prometheus*, *Pioneer*, the Reed to the *Pyramus* and Blechynden to the *Pomone*.

The Britomart, gunboat, in her first thirty hours' trial off Plymouth, maintained a speed of 11.2 knots with an indicated horsepower of 667. The mean results were: Air pressure, .24 inch; steam in boilers, starboard, 220 pounds; port, 220 pounds; steam at engines, starboard, 187 pounds; port, 208 pounds; vacuum, starboard, 26 inches; port, 25.4 inches; revolutions, starboard, 241.3; port, 238.1; indicated horsepower, starboard, 344; port, 323. On the eight hours' steam trial at 900 indicated horsepower, the mean results were: Steam in boilers, 208 pounds; steam at engines, starboard, 188 pounds; port, 196 pounds; revolutions, starboard, 274.8; port, 276.4; vacuum, starboard, 26.8 inches; port, 25 inches; indicated horsepower, starboard, 476; port, 481; total, 957; air pressure, 0.5 inch; coal consumption per indicated horsepower per hour, 2.52 pounds; speed, 13 knots. She had a four hours' forced-draft trial on the 25th ult., with the following results: Steam in boilers, starboard, 224 pounds; port, 224 pounds; steam at engines, starboard, 198 pounds; port, 198 pounds; air pressure, 1.2 inches; vacuum, starboard, 25.1 inches; port, 24.6 inches; revolutions, starboard, 309.6; port, 313.3; indicated horsepower, starboard, 661; port, 708; total, 1,369; speed, 14.6 knots.

Pandora.—The third-class cruiser *Pandora*, which was laid down in No. 11 dock at Portsmouth on January 3, 1898, was floated on the 17th inst. This vessel, which was designed by Sir William White, Director of Naval Construction, is one of two third-class unsheathed protected cruisers now building, the other, the *Pioneer*, being under construction at Chatham. Nine similar third-class cruisers, of a slightly less displacement, have already been launched and completed. The principal dimensions are: Length between perpendiculars, 305 feet; length over all, 318 feet 6 inches; breadth, extreme, 37 feet; mean draught of water, 13 feet 6 inches; displacement, 2,200 tons. A steel deck, sloped at the sides, and varying in thickness from ½ inch to 2 inches, has been worked throughout the length of the ship in the neighborhood of the water line, forming a watertight boundary and affording protection to the engines, boilers, maga-

* These trials made at end of 1898 subsequent to the publication of our table a year ago.
† These trials after ships had been refloated.
‡ This trial after new engines and boilers had been fitted.
The first nine vessels—to the *Hyacinth*—have Belleville boilers, although the steam generators of the *Gladiator* are not of the economizer type. The Yarrow boiler is fitted to the *Dwarf*, *Thistle* and *Bramble*, the Thornycroft to the *Perseus*, *Prometheus*, *Pioneer*, the Reed to the *Pyramus* and Blechynden to the *Pomone*.

zines, etc. The *Pandora* will be propelled by twin screws, each driven by an independent set of vertical triple-expansion engines, capable of developing, at the working pressure of 250 pounds to the square inch, an indicated horsepower of 3,500, or 7,000 for the two sets of engines. With this horsepower a speed of about 20 knots will be realized. Steam will be supplied by eight water-tube boilers of the Thornycroft type. These engines and boilers are being built in Portsmouth Yard. The quantity of coal carried at the above draught is 250 tons, although provision is made for stowing a much larger amount. The armament will consist of eight 4-inch quick-firing guns, two being on the forecastle, two on the poop, and the remainder in the waist of the ship—eight 3-pounder quick-firing guns, and three of .45-inch Maxims. Two above-water torpedo tubes will be carried. These tubes will be armored, the thickness of the armor varying from 1 inch to 3 inches. The complement of of the *Pandora* when commissioned will be 224 officers and men.

H. M. Cruiser Hyacinth completed her programme of speed trials off Plymouth on December 4th last. The engines are said to have worked smoothly throughout, the power developed being considerably in excess of the amount stipulated for in the conditions of contract. The mean results were as follows: Steam in boilers, starboard, 252 pounds; port, 251 pounds; steam at engines, starboard, 242 pounds; port, 240 pounds; vacuum, starboard, 25 inches; port, 26.9 inches; revolutions, starboard, 169.15; port, 173.55; indicated horsepower, starboard, 5,269; port, 5,267; total, 10,536; speed, 19.4 knots; coal consumption per indicated horsepower per hour, 1.58 pounds; air pressure, .25 inch for last five hours.

Goliath.—This battleship, whose first keel plate was laid on the slip on which she was built at Chatham Dockyard on January 4, 1897, and whose construction was so considerably delayed by the engineers' great strike that she was only put into the water at the end of last March, has now, after the vicissitudes often met with in first engine trials, finally completed those which were contracted for.

The two sets of engines are of the three-cylinder, inverted

triple-expansion type, each set driving a four-bladed screw propeller 16 feet 9 inches diameter; the collective horsepower to be developed by them upon an eight hours' full power trial being 13,500 indicated; steam being supplied by 20 Belleville boilers working at 300 pounds pressure per square inch.

The steam trials carried out were three in number—two of thirty hours' continuous steaming, the first at 2,700 and the second at 10,250 indicated horsepower, both of these being to test the coal consumption at these powers. The third trial was to be a continuous eight hours' run at full speed, or 13,500 indicated horsepower.

For the purposes of the first of these trials, the ship left Sheerness on September 27, and proceeded down the Channel, the engines working well for eighteen hours of the steaming time, till being off the Isle of Wight, when the joint of the high-pressure cylinder cover of the starboard engines gave out, and the set had to be put out of running until the fault was made good, the port set of engines continuing the running in the meantime, and developing 1,350 horsepower. After making good the defective jointing, etc., occupying seven hours, the thirty hours' trial was proceeded with to a satisfactory finish, the mean results attained being as follows: With the ship practically on an even keel, her water draught being 26 feet forward and aft, her boilers under a working steam pressure of 236 pounds per square inch, and the starboard and port engines running respectively at 65.8 and 65.6 revolutions per minute, the mean indicated horsepower realized by them was 1,467 and 1,340, or a total of 2,807, which exceeded that contracted for by 107 horsepower. This power was developed by a coal consumption of 1.73 pounds per indicated horsepower per hour, the speed of ship realized being 11.7 knots in the same time. This trial was completed on Friday, September 29, the ship having been abreast of the *Start*, when she sumed her trial run with both sets of engines.

On the 10th October the second coal-consumption trial of the *Goliath* at 10,250 horsepower took place to the westward of the Eddystone, commencing at noon of that day, and finishing on the evening of the 11th, the mean results attained at it being:

With the ship at the same water draught as on the first trial, and her boilers working at a pressure of 273 pounds per square inch, the starboard and port engines made 99.5 and 101.7 revolutions per minute, and developed 5,160 and 5,253 horsepower respectively, or a total of 10,413 indicated horsepower, being 163 in excess of the contract, the coal consumption being 1.54 pounds per indicated horsepower per hour, and the speed attained by the ship 17.1 to 17.32 knots in the same time. The stokeholes were under no air pressure during either of these coal-consumption trials.

Some defects having been discovered in the pump arrangements of the engines of the *Goliath* on the completion of the foregoing described trials, the ship was delayed till these were rectified before proceeding on the eight hours' full power trial, which took place in the Channel on November 22d, when the following satisfactory results were attained: With the ship at the same water draught as on the previous trials, and steam at a boiler pressure of 290 pounds per square inch, the revolutions of the starboard and port engines were 108.1 and 109.8 per minute, and the power developed by them 6,998 and 6,920 respectively, or a grand total of 13,918 indicated horsepower, being 418 in excess of that contracted for; an eminently satisfactory result, both engines and boilers having worked remarkably well, the coal consumption on the trial having been 1.91 pounds per indicated horsepower per hour, and the speed of the ship in the same time 18.4 knots.

As a battleship, or any class of warship, is seldom called upon to exceed the normal rate of steaming attained by her on a thirty hours' coal-consumption trial at four-fifths of her full power, the results given above show that the *Goliath*, as regards her capabilities in this direction, can claim to hold first place among the battleships of her class.

As a special interest is now being taken in the application of the latest improved Belleville boilers to warships, we give below, in tabulated form the results of practical tests made at the boiler works of John Penn and Sons at Deptford, with two of the boilers of the *Goliath*.

TEST TRIALS OF TWO OF THE BOILERS OF H. M. S. *GOLIATH*, MADE BY JOHN PENN AND SONS, AT DEPTFORD.

Date of trial, 1898	August 11.	August 12.
Duration of trial	4 hours.	4 hours.
Type of boiler, Belleville, with economizer	8-element.	9-element.
Number of boilers in use	1	1
Total area of fire grate in use, square feet	48.5	54.6
Total heating surface in use, square feet	*1,549.5	†1,766.3
Heating surface, grate area	31.95	32.35
(B) Steam pressure in boilers, pounds	298.75	300
Pressure of air in boiler-room (vacuum at base of funnel), inch of water	.875	.875
Furnace air pumps:		
Revolutions per minute	85	81.68
Pressure of air, pounds per square inch	12.625	12.56
Temperatures:		
Gases at base of funnel, degrees Fahrenheit	366.25	523.75
(A) Feed water, degrees Fahrenheit	58	58.25
Feed water on leaving economizer, degrees Fahrenheit,	246.31	255.25
Coal, Welsh, from Penllyn, Merthyr:		
Total used per hour, pounds	1,445	1,638
Per square foot of grate per hour, pounds	30	30
Approximate thickness of fires, inches (about)	5	5
Interval between firing each furnace, minutes	3	3
Feed water:		
Total used per hour, pounds	14,273	16,779
Per square foot of heating surface per hour, pounds	9.211	9.5
Per pound of coal, pounds	9.877	10.243
Equivalent evaporation to dry saturated steam:		
Per square foot of heating surface per hour:		
Based on (A) and (B), pounds	9.211	9.5
From and at 212 degrees Fahrenheit, pounds	11.274	11.618
Per pound of coal:		
Based on (A) and (B), pounds	9.877	10.243
From and at 212 degrees Fahrenheit, pounds	12.089	12.527
Evaporative power of the coal used (from and at 212 degrees Fahrenheit), ascertained by Thompson calorimeter	14.22	.....
Efficiency of boiler	.851	.88
Manner in which steam was disposed of, escaped to atmosphere.	Funnel blast.	Air blower and feed pump.

*995.2 boiler, 554.3 economizer. †1,119.6 boiler, 646.7 economizer.

Comparative Tests.—The second-class cruisers *Highflyer* and *Minerva* are to be placed in the balance in order to test

their respective steaming capacities. The two ships are the same in displacement and dimensions, but differ in armament, engines, and boilers. The *Highflyer's* engines develop 10,000 H.P. with natural draft; her boilers are of the Belleville type, eighteen in number, fitted with economizers. The *Minerva's* engines develop 9,600 H.P., and her boilers, eight in number, are of the Scotch type. The following trials are to be carried out:

No. of trials.	Series.	Duration in hours.	Speed.
3	A	60	10 knots.
2	B	60	14 knots.
2	C	60	17 knots.
2	E	12	Highest speed that can be maintained.
2	D	30	
2	F	12	

In series E the *Minerva* is to start with three boilers only lighted, and at a given signal to light the rest. The *Highflyer* will start with six six boilers lighted, and at the signal will light up the other twelve. This test is to ascertain the speed at one-third the full boiler power, though, as a matter of fact, the *Minerva's* three boilers are slightly in excess of one-third power. In series F each ship will start with one-third of the boilers alight, but in the *Minerva* the others will be banked and in the *Highflyer* fires only laid. After steaming from 18 to 36 hours at a low speed at a given signal the two will spread fires, or light fires, and put on all available steam. Each ship will, during the trials, carry an inspector of machinery, two additional engineer officers and a number of extra engine-room ratings.

Seagull.—This gunboat, equipped with Niclausse boilers, has made the first six of her nine 1,000-mile runs to test the boiler performance. The first four were at 1,350 I.H.P., and resulted in a coal consumption of about 1.87 pounds per horsepower per hour. The last two trials were at 1,600 I.H.P., and gave a consumption of about 1.7 pounds per horsepower per hour. The last trial of the above was in a heavy sea.—"Le Yacht."

FRANCE.

New Ships.—During the year 1900 the French navy will be supplemented by thirty-two vessels, made up as follows: Two battleships, one armored cruiser, one first-class cruiser, six destroyers, three gunboats, three submarine boats, six squadron torpedo boats, nine first-class torpedo boats, and one turbine torpedo boat. The programme further includes nineteen vessels for 1901, thirteen vessels for 1902, and three vessels for 1903 altogether; sixty-seven vessels.

New Cruiser.—A new cruiser of 12,416 tons will be bugun next year at Cherbourg. Her length will be 474 feet; beam, 71 feet; total I.H.P. of her three engines, 24,000; speed, 21 knots; effective radius, 10,000 miles at 10 knots. Her armament will consist of four guns of 7.6 inches, sixteen 6.3-inch Q.F., twenty 1.8-inch (3-pounders), four 1.4 inch (1-pounders), and five torpedo tubes, two to be submerged. She will cost about £1,170,000, which exceeds the cost of recent French battleships.

Amiral Aube.—The following details of the contract for the new French first-class armored cruiser *Amiral Aube*, which is to be built by the Société des Ateliers et Chantiers de la Loire, have been published. She is to be delivered at Brest ready for her trials on or before 11th of June, 1903. Her total cost, not including her armament, is to be £800,000. She is to be of the same type as the *Marseillaise*, building at Brest, her length being 453 feet and beam 66¼ feet. Her three engines will develop 20,500 H.P., their normal power being 10,000 H.P. Her coal consumption for the latter power will be 1½ pounds to 1¾ pounds per H.P. per hour. The protection for hull and guns will be of Harveyized steel.

Iéna.—The new first-class battleship *Iéna* was commissioned at Brest on the 1st ult., with a reduced crew for her trials, but she is far from being ready for them or from completion; nevertheless, no ship of her size has as yet been built so rapidly as she has been, for she was only laid down on the 15th January, 1898, being launched six months later. She is expected to attain a speed of 18 knots.

Guichen.—The new first-class cruiser *Guichen*, classed as a

croiseur-corsaire, successfully completed her steam trials off Toulon November 10, 1899. The mean speed realized in the three hours' trial was 23.5 knots, and one run gave a speed of 23.6 knots, exceeding the contract, which was for 23 knots, by $\frac{6}{10}$ of a knot. It may be affirmed that this speed has never been obtained in any other navy with a vessel of the *Guichen's* size, namely, 8,000 tons displacement. Notwithstanding the immense power developed (25,400 H.P.), the engines worked perfectly smoothly and without noise or vibration, and as the boiler pressure was easily maintained the *Guichen* will be certain to obtain on service the fine speed realized on her trials. The consumption of coal has been equally satisfactory, not exceeding 130 kilogrammes per square meter (27 pounds per square foot) of grate surface per hour, instead of 160 kilogrammes (32 pounds per square foot), which was expected. These results do the greatest honor to her constructors, the Chantiers de la Loire, the engines as well as hull being from the firm's own plans.—"Journal Royal United Service."

The Goubet Submarine Boat.—A despatch from Paris gives some interesting details of the recent experiments at Toulon with the submarine boat *Goubet*. The tests are said to have been successful. The boat carried a crew of three men. It plunged down five meters (16.4 feet) below the surface and remained submerged for five hours. Upon arriving at the surface the crew was well and had suffered no inconvenience. At another trial the *Goubet*, preceded by a launch to give warning, crossed the roadstead with its dome twenty-five centimeters (9.8 inches) below water. It also made two instantaneous descents, traveling under water fifty-six meters (61.2 yards) during each one. In spite of a heavy swell the submarine boat gave evidence of remarkable stability. Finally, near Fort Eguillette, the *Goubet* again disappeared under the surface and remained hidden for twenty minutes. It was impossible for those following the experiments in the accompanying launch to discover the *Goubet's* whereabouts until she appeared again on the surface.—"Electrical World and Engineer."

Gaulois vs. Charlemagne.—The following are comparative

details of the trials of the new first-class battleships *Gaulois* and *Charlemagne*, twenty-four hours' run at two-thirds speed:

Gaulois.—I.H.P., 9,200; corresponding speed, 16.5 knots; consumption of coal per H.P. per hour, 0.695 kilogramme.

Charlemagne.—I.H.P., 9,270; corresponding speed, 16.41 knots; consumption of coal per H.P. per hour, 0.703 kilogramme.

The results of the three hours' run at full speed under forced draft, for which the contract I.H.P. was to be 14,500, were as follows:

Gaulois.—I.H.P., 14,925; corresponding speed, 18.02 knots; consumption of coal per H.P. per hour, 0.808 kilogramme.

Charlemagne.—I.H.P., 15,235; corresponding speed, 18.136 knots; consumption of coal per H.P. per hour, 0.871 kilogramme.

GERMANY.

Kaiser Karl der Grosse.—On the 18th October last, from the yard of Blohm and Voss, at Hamburg, in the presence of the Kaiser and a distinguished company, was launched the new first-class battleship *Kaiser Karl der Grosse.*

The dimensions of the new battleship are as follows: Length, 377 feet 6 inches; beam, 66 feet 10 inches; displacement, about 12,000 tons, with a mean draught of 25 feet 9 inches. Protection is afforded by a water-line belt of Krupp steel extending from the ram for four-fifths the length of the ship, having a maximum thickness of 12 inches tapering to 5.5 inches; the turrets for the heavy guns have 10-inch armor and the small turrets and casemates for the secondary battery 6-inch. There are two conning towers, one forward with 10-inch armor, and one aft with 4-inch; the armored deck will be 3 inches and the armored ammunition tubes 4 inches, all the armor being of hardened steel by the Krupp process.

The armament will consist of forty-six guns of different caliber, thirty-four of which will be Q.F. and twelve small machine guns. The heavy guns will be four 24-centimeter (9.4-inch) Q.F. 50-caliber guns, mounted in pairs, two in a turret forward and two in a turret aft; the secondary battery will consist of eighteen 15-centimeter (5.8-inch) Q.F. 40-caliber guns, twelve being mounted

in casemates and six in small turrets, and twelve 8.8-centimeter (3.3-inch) Q.F. 40-caliber guns behind shields. There will also be six torpedo tubes, five submerged, one in the bow and two on each broadside, and one above water in the stern. The ship will be driven by three propellers, and the engines are to develop 13,000 I.H.P., giving a speed of 18 knots; the boilers will be water-tube, type not yet decided. The coal stowage will be 650 tons. The ship will have two funnels and two military masts with fighting tops. The ship was laid down in the spring of 1898, and is to be ready for her trials in the spring of 1902.

Nymphe.—A small cruiser, *A*, has been launched from the Germania Yard at Kiel and christened the *Nymphe*. Her dimensions are as follows: Length, 328 feet; beam, 39 feet; displacement, 2,600 tons, with a mean draught of 14 feet. She is of the improved *Gazelle* type. Her engines are to develop 8,000 I.H.P., which are to give a speed of 21.5 knots, instead of 19.5, the speed of the first of the class. Her boilers will be water-tube on the new Schulz system, and she will have a 2-inch armored steel deck. Her armament will consist of ten 10.5-centimeter (4.1-inch) Q.F. guns, fourteen 3.7-centimeter (1.9-inch) Q.F. guns and four machine guns, with three torpedo tubes, two submerged on the broadside and one above water in the stem.

Ships Under Construction.—The following ships are on the stocks at present: First-class battleships: *A*, at the Schichau Yard, Danzig; *C*, at the Imperial Dockyard at Wilhelmshaven; *D*, at the Vulcan Yard, Bredow, near Stettin; *E*, at the Germania Yard, Kiel. First-class armored cruisers: *A*, at the Imperial Dockyard, Kiel. Third-class cruisers: *C*, at the Imperial Dockyard, Wilhelmshaven; *D*, at the Schichau Yard, Danzig, and *E*, at the Germania Yard, Kiel.—"Royal United Service Journal."

Repair Ship.—The great cruiser *Kaiser*, which was recently placed out of commission, is not to be used as active cruiser on account of her being obsolete. It is planned, however, to convert her into a repair ship, and, fitted out with all necessary materials for provisional repairs, she is intended to go with large fleet maneuvers, and, in case of war, to be attached to the fleet.

JAPAN.

The Japanese Destroyers.—The successful termination of the trials of the Japanese destroyer *Niji* brings to a completion the work on a group of six vessels which are certainly remarkable even in these days of high-speed craft.

The six boats have all been built and engined by Messrs. Yarrow and Co., of Poplar, and their completion puts Japan's navy in possession of a division of torpedo craft unexcelled in the world.

The boats are 220 feet long and 20 feet 6 inches wide. They are twin-screw and have each two sets of four-crank triple-expansion engines, with cylinders 20½ inches, 31½ inches, and two low-pressure cylinders each 34 inches in diameter, the stroke being 18 inches. These engines are designed to give 6,000 horsepower, but no doubt 7,000 could be reached if needed. There is one 12-pounder quick-firing gun mounted aft and five 6-pounder guns. There are two torpedo guns for 18-inch torpedoes.

The following is a list of the six vessels.

	Speed (under Admiralty Conditions (of Trial). Knots.	Air Pressure. Inches.
Ikadsuchi,	31.32	2.5
Inadsuma,	31.037	2.2
Akebono,	31.08	1.7
Sazanami,	31.382	1.3
Ovoro,	31.262	1.3
Niji,	31.15	0.9

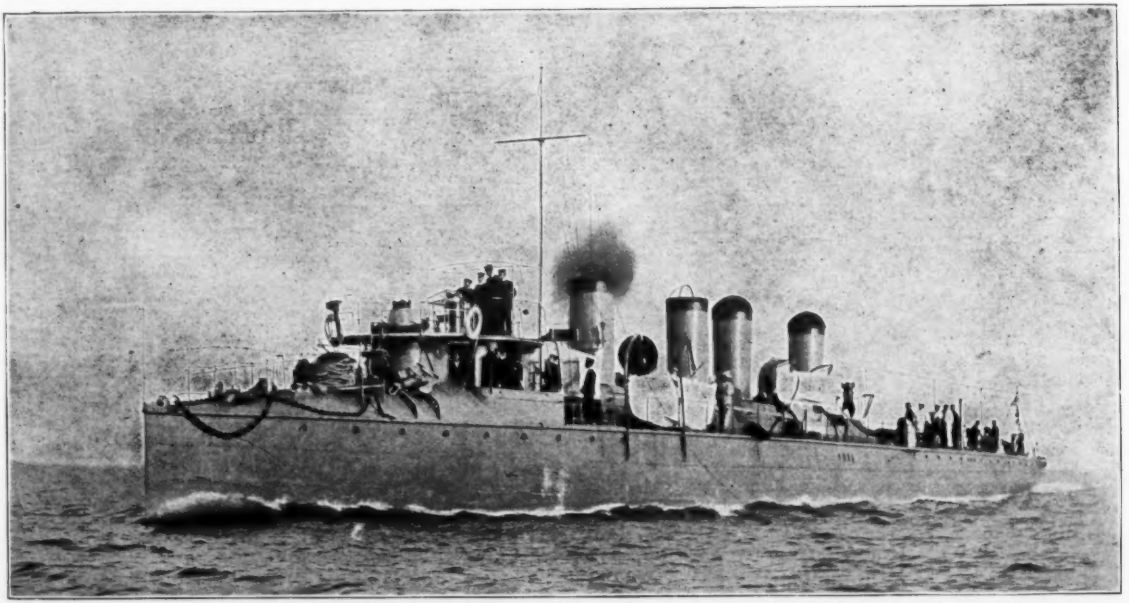
The contract speed was 31 knots, carrying 35 tons load, on a three hours' continuous run, *i. e.*, the same conditions as demanded by the British Admiralty for their 30-knot destroyers. A point which all engineers will appreciate is the low air pressure with which the speeds were obtained, especially in the later boats. Appended is a detailed report of the official trial of the last of the six destroyers, the *Niji*. She was launched on December 16, the first preliminary trial took place on December

18, and the official trial on December 21; so that there was a gap of only five days between the launching and the official trial. On the *Niji*, the air pressure during the three hours' run varied from $\frac{3}{4}$ inch to $\frac{1}{8}$ inch, and the consumption of coal for the three hours worked out at 1.98 pounds per indicated horsepower per hour. The consumption per square foot of grate was 52.3 pounds. There were four Yarrow straight-tube boilers for the supply of steam, and, although the grates are large in proportion to what is customary, with a little experience there was no difficulty in stoking, as the results obtained indicate. It will be noticed that from the commencement to the end of the trials there was a steady advance in performance. This is to be attributed to various improvements introduced as experience suggested.

Three of the vessels are now out in Japan, one in the China seas on her way out, the fifth has left London within the last few days, and the *Niji* will be starting shortly.

The engines are balanced on the Yarrow, Schlick and Tweedy system, and the absence of vibration at all speeds was considered by the Japanese authorities to be highly satisfactory.

A detail in these boats, as well as of others built by Messrs. Yarrow & Co., which deserves attention, is the system adopted in the steam pipes for allowing for variations in length. (See description in Vol. XI, No. 3, page 698 of the JOURNAL.) It will be remembered that instead of the ordinary stuffing-box arrangement allowing the steam pipes to work in and out of a socket, there is a special swivel joint, something similar to that adopted in an ordinary gas bracket, but it is so arranged as to be in perfect equilibrium. In vessels of light construction, such as torpedo boats or destroyers, not only is it needful to provide against variation in length, due to change of temperature, but it is also necessary to supply some ready means of obtaining sufficient elasticity in the system of steam pipes, so that they can accommodate themselves to the flexibility of the hull. This is considerable when the vessels meet with rough weather. Messrs. Yarrow are of opinion that there is more risk of accident to steam pipes from the constantly varying movements of the hull



THE "NIJI" CLASS—JAPANESE DESTROYERS.

than from expansion through change of temperature, it being remembered that the bending of pipes because of hull movement is constantly going on in rough weather, while the expansion and contraction of pipes through changes of temperature is comparatively infrequent.

In four of the vessels each boiler is provided with an independent feed pump, this being considered the safest and most efficient method of feeding boilers. In the last two boats, however, with a view to test the comparative merits of the systems, two of the boilers were supplied with water by ordinary feed pumps worked off the main engines.

Provision is made on board for 90 to 100 tons of coal, and this bunker capacity is found to be amply sufficient to make any of the runs at from 11 to 14 knots between the coaling stations on the voyage to Japan.

OFFICIAL TRIAL, DECEMBER 21, 1899, OF THE *NIJI*.

Draught of water to bottom of propellers, 7 feet 10 inches aft, 4 feet 11 inches forward.
Load carried, 35 tons. Runs on the Maplin Mile.

Runs.	Boiler steam.	First receiver.	Second receiver.	Mean vacuum.	Air pressure.	Mean revolutions.	Time.	Speed.	First mean.	Second mean.	Admiralty mean.
				ins.	*ins.*		*m. s.*				*knots.*
1	203½	52	8	24		390.24	2′ 4	29.032	31.060		
2	206	52	7⅞	24		367.13	1′ 48⅘	33.088		31.019	
3	204	52¼	6⅞	23⅞		384.44	2′ 4⅕	28.869	30.978	31.070	31.106
4	205	52½	7	23⅞		367.54	1′ 47⅘	33.457	31.163	31.145	
5	204	52¼	6⅞	23⅞		387.12	2′ 5	28.800	31.128	31.190	
6	204	52⅜	6¾	23¾		387.92	1′ 46⅘	33.707	31.253		
Mean on miles.	204½	52¼	7	23¾	¾	387.4	...	...	...	...	...

Means for three-hours' trial: 204 pounds steam, 53 pounds in first receiver, 7 pounds in second receiver, 23¾ inches vacuum, ¾ inch to ⅞ inch air pressure in stokehold. Mean revolutions per minute, 388.06. Mean speed during three hours, 31.156 knots.

Usugumo.—The 30-knot torpedo boat destroyer *Usugumo*, the sixth vessel of this type built for the Japanese Government by Messrs John I. Thornycroft & Co., of Chiswick, was successfully launched from their yard on the 16th of January, 1900. The vessel was launched complete, with machinery on board and steam up and ready to begin the official speed trials.

On January 23d a satisfactory full-power trial was made, resulting in a speed of 30.602 knots on the measured mile, and 30.37 knots for three hours' run.

RUSSIA.

Sevastopol.—An official trial of the engines of this first-class battleship, 10,200 tons, in the presence of a commission presided over by Rear-Admiral Amosov, at full power and lasting six hours, was carried out on the measured mile at Kronstadt. They were very satisfactory. The estimate was that both engines on an average should develop 10,600 H.P., at 95 revolutions of each screw and 150 pounds pressure of steam. The expenditure of coal was 2 pounds per hour per H.P.

Peresviet.—The trials of the engines of this first-class battleship gave as the result of eight series of diagrams the following: Highest pressure cylinder, 1,405.15 H.P.; medium, 1,527.37 H.P.; lowest, 1,633.69; total, 4,566.21, or for the three engines, with an average pressure of steam to the square inch of 169.5 pounds, a result of 14,532 H.P., or some 32 more than the contract.

She and her sister ships, the *Osliabia* and *Pobieda*, are considered in Russia a happy combination of battleship and cruiser, having the protection of vital parts and armament, the numerous guns and solidity of the one with the speed, range of action and seaworthiness of the latter. She has some new features as Russian ships go, her three distinct engines, each with a separate screw, her 6-inch guns are each in a casemate with 2 to 5 inches of armor, and electricity is used to a hitherto unknown extent, and her six dynamos give 6,000 ampères at 100 volts. She can be steered by hand, the steam transmission engine with cylindrical or electricity, besides Paidâsi's hydraulic and Shubin's electrical modes of transmission, or five different methods in all. Her engines are well protected by an armored deck and have very small hatches.

New Cruiser.—The first ship to be constructed at the new works at Windau will be a cruiser with protected deck. Her displacement will be 6,375 tons; length, 412 feet; beam, 53½ feet; draught with full load, 20 feet 8 inches; speed, 23 knots. Her engines are to develop 20,000 H.P. Steam will be provided by water-tube boilers of the Normand type. She will have two masts, each with a fighting top, and two bridges. The deck

protection will be 2 centimeters in thickness along the whole length. Her armament will consist of twelve 6-inch Canet guns, 45-caliber, two in a fore and two in an aft turret, and eight in the casemates; twelve 7.5 centimeter, 50-caliber guns in the battery, and eight 4.7-centimeter Hotchkiss guns; also five torpedo tubes, two under water broadside forward and three above water, two broadside aft, and one right in the bows. Her freeboard will be 20 feet 6 inches.

Cesarevich.—This first-class battleship, building at the Forges et Chantiers de la Méditerranée, at La Seyne, is of the type of the *Jaurêguiberry*, and all the steel employed will be Siemens-Martin. Her dimensions will be as follows: Length, 388 feet 9 inches; beam, 75 feet 6 inches, with a displacement of 12,900 tons. The plates of the upper armored deck and the communication and ammunition tubes will be of a special quality of steel employed in the French Navy, the latter 5 inches thick. The battery deck will be covered with linoleum, as will the upper armored deck, which is made of two thicknesses of $\frac{1}{8}$-inch steel. The water-line belt, which goes from end to end, tapers from 8 inches amidships to 4 inches at the extremities. Above again is another belt of 6-inch steel extending to the main deck, while the casemates for the secondary battery will be 5 inches thick, the armor on the barbettes being 10 inches. The armament will consist of four 12-inch guns, twelve 6-inch Q.F., twenty 12-pounder Q.F., and twenty-eight smaller Q.F. guns. There are four under-water torpedo tubes and two above water in the bows. She will be furnished with torpedo nettings. The contract speed is to be 18 knots on a 12-hour trial.

MERCHANT STEAMERS.

El Cid.—This elegant freight steamer, the last of a quartette of steamships constructed by the Newport News Shipbuilding & Dry Dock Co. for the Morgan Line, to ply between this port and New Orleans, arrived here December 17th from the yard of her builders. The four sister ships have been built since the Spanish-American war to replace those sold to the Government for auxiliary cruisers. These ships, the finest and fastest freight steamers in the world, have all been built under the superintendence of Horace See, of New York. The principal dimensions are: Length over all, 406 feet; length between stem and propeller post, 380 feet 8½ inches; breadth molded, 48 feet; depth molded to awning deck, 33 feet and 9 inches; gross tonnage, 4,665 tons; net tonnage, 2,905 tons. The hull is of steel throughout, the outside plating having vertical lap joints below the water line. There are three continuous decks and partial orlop deck at forward end of forehold. The deck houses, as in the case of all of the late vessels of the line, are of steel with round side lights. She has two cross hatches with an improved arrangement of covers for convenience in handling, etc. The rudder is built up with center plate and made with stock in two pieces, coupled together below counter. The vessel is provided with steam steering gear at forward pilot house, and a screw hand gear at the after house. A flying bridge connects the forward house with the main house. Steam windlass and steam capstans are provided for handling anchors, hawsers, etc. A complete eleotric-light plant, with 112 incandescent lamps of 16 candlepower each, in engine room, deck houses and crew space; portable lamps in cargo space, masthead light of 50 candlepower, side lights and a powerful search light placed on a stand on foremast. This stand is arranged similar to the crow's nest on the transatlantic ships and can be used for a lookout.

The engines are of the triple-expansion type, cylinders 33, 52 and 84 inches diameter, 54 inches stroke. In the high-pressure and intermediate valve gear, levers are introduced and connected to the valve stem and valve gear in such a manner as to cause the weight of the valve to counterbalance the weight of the connections below the lever, thereby dispensing with counterbalancing cylinders. The engines are reversed by steam, and controlled by a governor. The main pistons are constructed so as to dispense with the employment of tail rods, and will at the same time be steam tight without undue friction. The piston rods and valve stems are fitted with improved packing. The crank-shafts and crank-pins are 16½ inches diameter. The shaft is fitted with adjustable thrust bearings, one for go ahead and another for backing. The air pumps, single-acting, are 32 inches diameter. Total cooling surface in condenser is 6,400 square feet. An independent centrifugal circulating pump is connected to the condenser, sea, bilge and ballast tank. The propeller is built up, the hub being of iron and the blades of manganese-bronze. Steam is furnished by three double-ended boilers, 13 feet 10 inches diameter and 20½ feet long; working steam pressure, 180 pounds. The *El Cid* was built under the rules of the American Bureau of Shipping to class A1 for 20 years in the Record of American and Foreign Shipping.

St. Louis.—The steamer *St. Louis*, of the American line, made a notable record during the past year in covering the greatest distance ever traversed in a similar space of time by any production of man's ingenuity propelled by its own motive power. In thirty-four voyages across the Atlantic between Southampton and New York this American-built steamer traveled 106,764½ miles and carried 16,858 passengers, of which number 5,981 were first class. There may be Pullman cars on transcontinental trains which in constant service have traversed more than 106,000 miles within a year, but no locomotive or other vehicle propelled by its own power has approached the record of the *St. Louis*. She was in commission continuously during all save two weeks and had not a single mishap. The average for the *St. Louis* for the 365 days in the year is 292 miles. Taking

into consideration the fact that the steamer was in port during 133 days, it will be seen that her actual average steaming was 460 miles a day.

Grecian.—The steamship *Grecian*, which was launched on January 6, is the fourth ship built at the works of the Harlan & Hollingsworth Company for the Boston and Philadelphia Steamship Company, familiarly known as the Winsor Line, the others having been the *Indian*, *Spartan* and *Parthian*, and is the eighth ship turned out by that company during the year 1899. She is a three-deck freight and passenger steamer, built to rate for 17 years, has a tonnage of 2,483.08, length over all, 290 feet; between perpendiculars, 263 feet 3½ inches; beam, molded, 42 feet; depth, 36 feet, and will have a draft, loaded, of 18 to 20 feet and a carrying capacity of about 2,500 tons. Has four watertight bulkheads, four hatches, four side ports on each side, four single-cylinder Williamson winches; Hyde steam capstan, windlass forward and aft; two steel masts, together with steel deckhouse with accommodations for about 100 passengers. Has two electric-light plants, 200 lights each; 18-inch searchlight. Inverted, triple-expansion engines, 25 by 41½ by 66 by 42-inch stroke, with four 13 by 10½-foot boilers, each with two furnaces 40 inches inside diameter, built to sustain a working pressure of 170 pounds. Built-up cast-iron wheel, 15 feet diameter. Ellis & Eaves induced draft; bunker capacity 275 tons, and is to make a speed of 15¾ knots on an 8-hour trial.

Deutschland.—This steamer, built for the Hamburg-American Line by the Vulcan Company in Stettin and launched on the 10th of January, is to begin its regular trips between Hamburg and New York this summer. Its principal dimensions are:

Length on deck, 684 feet; beam, 67 feet; depth to the upper deck, 99.8 feet; displacement at full load (29-foot draught), 23,200 tons; registered tons, 16,200; launching weight, 9,300 tons; contract speed, 23 knots.

The ship, therefore, exceeds the *Kaiser Wilhelm der Grosse*, built by the Vulcan Company in 1897, by 36 feet in length and 9.8 feet in beam.

The hull is built of German steel, after the regulations of the

German Lloyd for the highest class, and is built with four decks with extensive strengthening; is provided with double bottoms throughout its entire length, and is divided by fifteen cross bulkheads, and one longitudinal bulkhead in the engine room, into seventeen water-tight compartments; so that the ship would remain floating, even after filling two neighboring compartments. The bulkheads are built after the latest instructions of the German Lloyd, and have ample thickness to resist even one-sided water pressure. For the removal of water entering the ship there are placed on the deck four centrifugal pumps, two machine bilge pumps, and six duplex pumps, which altogether can throw 4,000 tons of water per hour.

The ship is schooner rigged, with two steel hollow masts. It has four steel decks. Above the upper deck are superstructures, one 115-foot poop deck, one bridge structure 410 feet long, and a quarter deck 284 feet long. Above the bridge and poop there is a promenade deck 534 feet long, and over this is the open deck. The ship can accommodate 467 first-class passengers, 300 second-class and 290 third-class. To this must be added the crew, consisting of 525 men. Besides these staterooms, there are provided for several first-class passengers special apartments, consisting of drawing, bed and bath rooms and about 50 extra large rooms intended for one person alone. For the first-class passengers there is a dining room with 362 seats, and saloon and large smoking room on the bridge deck, a breakfast room and a children's parlor on the open deck, and finally a large promenade deck protected from rain and sun. The rooms for the second-class passengers are aft, partly on the upper deck, partly on the main and between deck. On the main deck is a saloon with 166 seats, on the upper deck a parlor, and on the poop deck a smoking room.

All inhabitable rooms are liberally provided with electric illumination, steam heating, ventilation and call bells; the engine and boiler rooms are also illuminated electrically. There are, in all, about 2,000 electric lamps supplied from five dynamos, three of 700 ampères and two of 400 ampères, all of 110 volts.

The coal bunkers hold about 4,850 tons. For the transport

of cargo, baggage and supplies there are sixteen hoists, of which two are aft, two on the upper deck, and two on the open deck. The ship has twenty life boats, of which four are permanently hanging in davits. Of these, sixteen are steel boats of the Francis patent, the others of wood. That they may be worked quickly, there are four steam hoists on the open deck.

It may be specially mentioned that this steamer is built in accordance with the instructions of the Imperial German Navy, that she may serve as man-of-war, as a cruiser provided with a large number of guns. For this purpose the rudder and steering gear are placed under water.

The engine and boiler plant, also installed by the Vulcan Company, consists of two 6-cylinder quadruple-expansion engines, arranged according to the Schlick system. They will indicate a total of 33,000 horsepower, with 76 revolutions per minute. Each of these engines has a shafting line about 131 feet long, of 24.9 inches diameter, one bronze screw of 21.6 feet diameter. The crankshaft, each of four cranks, and the propeller shafts of 24.9 inches diameter, are of nickel-steel, the other shafting of the best Siemens-Martin steel.

Steam is furnished by twelve double and four single boilers, with 112 fires and a total heating surface of 86,200 square feet, working at a pressure of 225 pounds per square inch. The boilers are arranged in four groups, of which each has a stack of 13 feet diameter, and 115 feet height. The boilers are to work under forced draft, and each group will have four blowers of 10 feet diameter, driven by compound engines. There are on board of this steamer nearly 68 steam engines, with 124 steam cylinders.

Strombus.—The steamship *Strombus* was taken for trial on the 16th inst. by Messrs. Sir W. G. Armstrong, Whitworth & Co., Limited, of Newcastle, by whom she has been specially constructed for the Shell Transport & Trading Co., of London, to carry petroleum in bulk and general cargo. Amongst other features she has been designed for the burning of liquid fuel. Her principal dimensions are: Length between perpendiculars, 410 feet; beam, 52 feet; depth molded, 33 feet 9 inches, with a total deadweight capacity of 8,450 tons. The whole of the fore

part is reserved for cargo space, the engines and accommodation for the engineer officers being aft, and the accommodation for the captain and his deck officers in the bridges. The crew is housed in the spacious forecastles forward. The liquid fuel arrangements have been subjected to exhaustive trials, and have proved in every way satisfactory, the steam being well maintained. On the trial trip the average speed was 10.6 knots. There is one triple-expansion main engine, built by the North-eastern Marine Engineering Co., Limited, Sunderland, having cylinders 28 inches, 46 inches and 77 inches in diameter, with a 48-inch stroke, and taking steam from three large single-ended four-furnaced boilers, at a working pressure of 180 pounds per square inch.

This is the largest steamer burning oil in the world, and also the largest tank steamer afloat.

The boilers will use oil fuel as soon as the steamer reaches the oil fields, and the furnaces are so arranged that they can be quickly changed from coal burning to oil burning and *vice versa*. All that is necessary is shifting of grate bars and put in fire-brick arches, the oil burners remaining as fixtures.

There is one oil burner in the center of each furnace door; it consists of two concentric cones, one for the oil and one for the steam which is used to pulverize the oil. When not in use these burners swing back out of the way by means of trunnion bearings in the pipes. The oil is carried in bunkers or tanks, of which the fire-room bulkheads form one side, so that the only protection between the oil and the fire room is this one plate. These tanks when using coal are used as coal bunkers, and are fitted at the level of the floor plates with a plate the size of a bunker door which can be removed and used for getting out the coal. The oil is pumped from the large tanks or bunkers to a distributing tank at the upper deck, and flows from there by gravity to the several burners. This distributing tank serves a double purpose, as it allows the oil and water to separate, and makes the burners work more uniformly. There is a drain valve and pipe in the oil pipes leading to the burners, and they kept a bucket about half full by opening this drain. During the dock

trial this bucket was close to the mouth of one of the furnaces, but the men did not seem to think that it was any cause of alarm to have oil in the fire room, and when they wanted to relight any of the burners they would stick a swab into this bucket and then light it in one of the other furnaces, and after the burner was started they would extinguish the swab by sticking it into the pail of oil.

The noise of the burners was very great, and verbal communication was very difficult in the fire rooms, and the heat radiated from the furnaces and ash pans was intense.

The oil and the steam is led through pipes in the uptake and through a portion of the furnace so as to get them as hot as possible before they reach the burners. The burner consists of three concentric cones, one for oil, one for steam and the third for air. The air is drawn in by induction from the steam flowing past the mouth of the cone, and before it reaches the burner it passes through pipes the same as the oil in order to heat it.

Saxonia.—On Saturday, the 16th inst., Messrs. John Brown and Company, Limited, Clydebank, launched the *Saxonia*, a twin-screw steamer of about 14,000 tons gross, which they have built for the intermediate Atlantic service of the Cunard Line. More than ordinary interest centered in the floating of the vessel, for she is not only the biggest ever built on the Clyde, but is also one of the ten largest in the world. The dimensions of the *Saxonia* are: Length, between perpendiculars, 580 feet; length over all, 600 feet; breadth, extreme, 64 feet 3 inches; molded depth from upper deck, 41 feet 6 inches. The vessel is of the complete shelter-deck type, with lofty erections amidships intended for the accommodation of passengers. The number provided for are, first-class, 164, and third-class, about 500. There is also provision for a very large number of steerage passengers.

A special feature has been made of the third-class accommodation. The rooms are arranged to accommodate four persons each, and are fitted up in a most comfortable, not to say luxurious, style. The whole of this accommodation is fitted so as to be readily removed in case the space is required for cargo. The whole of the upper deck at the after end will be fitted for the safe carriage of horses and cattle. Twin-screws have been provided,

each actuated by quadruple-expansion engines, and the steam is supplied from nine single-ended boilers working under forced draft.

Persic.—The new White Star steamship *Persic* has arrived in the Mersey from Messrs. Harland and Wolff's yard at Belfast. The *Persic* is in all respects similar to her sister ships, the *Afric* and *Medic*, already in the trade, save only some trifling improvements, which. by reason of later experience, it has been found possible to introduce. Her dimensions are: Length between perpendiculars, 550 feet; breadth, 63 feet; depth, 44 feet; gross tonnage, 11,984 tons. In the *Persic* and her four sisters, including the *Runic* and *Suevic*, to be launched next year, accommodation of an exceptional character has been provided for 350 passengers, including comfortable reading, smoking and dining rooms, also excellent baths and lavatories. The engines are of the four-crank, vertical, quadruple-expansion type, balanced on the Schlick system, and drive twin propellers. The *Persic* is the seventeenth steamer in the White Star fleet propelled by twin screws.

Crown Point.—Messrs. Joseph L. Thompson & Sons, Limited, North Sands, Sunderland, launched on December 30 a steel screw steamer, built to the order of the Norfolk and North American Steamship Company, Limited, of 1 Crosby Square, London, E. C., and named the *Crown Point*. The vessel is 390 feet long between perpendiculars, and has a beam of 51 feet, with a molded depth of 30 feet 6 inches. She is built especially to meet the requirements of the cattle trade and for the Manchester Canal, with sixteen derricks, ten steam winches, and all the most modern machinery for the rapid handling of cargoes. Her deadweight capacity is about 7,500 tons, and provision is made for the carrying of 1,900 tons of water ballast in the cellular double bottom, and a large, deep tank fitted immediately aft of the engine room, and extending to the main deck. The engines are being built by Messrs. J. Dickinson & Son, Limited, Palmer's Hill Engine Works, Sunderland, and are of the triple-expansion type, the sizes of the cylinders being 25 inches, 43 inches and 74 inches, by 48-inch stroke, with three single-ended boilers working at 200 pounds pressure of steam, and fitted with Howden's forced draft.

YACHTS.

Dreamer.—On the official trial of this new steam yacht, owned by Thomas W. Lawson, of Boston, the guaranteed speeds of 12 and 14 knots under natural and forced draft, respectively, were easily exceeded. The speeds attained were 13.13 knots under natural and 14.80 under forced draft. The yacht made several bursts of speed of more than 15 knots, and the day before ran for a short time at the rate of 16¼ knots. None of the numerous yachts built recently has attracted more favorable comment and attention than the *Dreamer*. Tams, Lemoine & Crane, the designers, and Lewis Nixon, the builder, have combined to produce one of the most perfectly built, elegantly finished and luxuriously fitted-out boats in American waters. The dimensions of the *Dreamer*, as given by Mr. Nixon, are: Length over all, 175 feet; length on water line, 148 feet; beam, 24 feet, and draught, 9 feet 6 inches. She is fitted with a triple-expansion engine, having cylinders 14.21 and 36 inches in diameter by 24 inches stroke, steam being furnished by two large Almy boilers. The vessel has a steam-steering engine, an ice plant, an electric windlass, electric lights and heaters, searchlights and every modern appliance adding to efficiency or comfort. The large deck-house and bulwarks are paneled in teak. The staterooms are finished in mahogany, bird's-eye maple, quartered oak and tapestry panels. There are four bath rooms with tiled floors in the owner's quarters. He has eight large staterooms and a large music room below, and dining room, boudoir and smoking room in the deck house. The *Dreamer* is the fifth yacht built by Mr. Nixon, the preceding ones being the *Freelance*, the *Josephine*, the *Elreba* and the *Columbia*.—"American Shipbuilder."

Margarita.—The steam yacht *Margarita*, now building at the Scott Yard, Greenock, on the Clyde, for A. J. Drexel, of Philadelphia, is a Watson design, and is a large, full-powered, sea-

going vessel. Her principal dimensions are: Length over all, 323 feet; load-water line, 272 feet; beam, extreme, 36 feet 7 inches; load draught, 16 feet 8 inches. She will have the usual clipper bow, overhung stern, two pole masts, with a fore-and-aft sail spread and one funnel. She is flush decked, the side plating being carried up at the ends, with rail carried on stanchions along the sides of the main deck.

Steel is, of course, the material used for the construction of the hull and also of the decks, the latter being covered with teak. A double bottom is carried the entire length, and there are ten watertight compartments in all. There is a large amount of promenade space on the main deck, as the deck house is not continuous. Just aft of the foremast a small house contains the smoking room and spacious vestibule, with staircase communicating with the chart room and pilot house above and living rooms below. Abaft the funnel there is a spacious skylight, or dome, over the main dining room, and aft of this come the engine casing and deck house, containing vestibule and boudoir, all of steel, paneled with teak wood.

The *Margarita* will have twin screws, driven by triple-expansion engines of about 5,000 I.H.P., designed to give a trial speed of 17 knots. Boilers will be of the cylindrical, multitubular type. The coal capacity figures out 550 tons, and there is large water capacity in the double bottom and tanks. A modern equipment of auxiliaries will be carried, including a refrigerating plant with a rated capacity of 1,200 pounds of ice a day, electric-lighting plant of 800 lights capacity, and an extensive system of mechanical ventilation.

As customary in vessels of this class, the scheme of decorating and finishing is very elaborate. The drawing room, which will extend the entire width of the ship, will be finished in Louis XV style, the dining room in Chippendale, and the social hall or library in Empire style. In this room the woodwork will be carved Spanish mahogany, with decorated stained-glass dome. The smoking room in the forward main-deck house will be treated in old English style, with oak paneling, and the boudoir in the after house will be finished in white wood. A rail will be

carried around the top of the after house, and this space will be used as an observation platform by the guests. A feature of the equipment will be an armory supplied with rifle-caliber automatic guns and small arms.

Eight boats will be supplied, including a steam and a naphtha launch. A crew of sixty-eight men all told will be carried.

It has been the intention to build a roomy, habitable boat in which long voyages can be undertaken in comfort.—"Marine Engineering."

OBITUARY.

S. DANA GREENE.

Through a most distressing and lamentable catastrophe on the evening of January 8, this widely-known and universally-esteemed ex-officer of the Navy, lost his life, and the JOURNAL has never been called upon to chronicle a death where sadder circumstances surrounded the casualty.

Mr. Greene, while skating on the Mohawk river at Schenectady, N. Y., and in company with his wife, undertook to enjoy a rapid flight on the ice, before the strong wind that was then blowing, by using what is called a skating sail. Before the couple had sped more than half a mile they disappeared through the ice, having been driven into a cut from which the thick ice had recently been removed, and where a new coating had scarcely begun to form. Both were drowned before assistance could reach them, although their cries for help were heard and every endeavor made to save them.

Mr. Greene was 35 years old and was the son of Commander Samuel Dana Greene, U. S. N., who was second in command on the *Monitor* during her famous fight with the *Merrimac* in Hampton Roads. S. Dana Greene started his life's work in his father's profession, having graduated from the U. S. Naval Academy at Annapolis with high honors in 1883. On July 1, 1885, he received his commission as ensign and remained in the Navy until 1888, when he resigned to take up electrical engineering work. For some years Mr. Greene was chief engineer of the Sprague Electric Railway & Motor Co., which position he resigned to connect himself with the General Electric Co. Mrs. Greene was formerly Miss Cornelia Chandler, daughter of Rear Admiral Chandler, U. S. N.

During the Spanish-American war, Mr. Greene, who had taken great interest in the formation of the Naval Reserve, went to the front, and was under fire as the executive officer of the auxiliary

cruiser *Yankee*. Since the peace he had been serving on the staff of Governor Roosevelt, of New York State, as naval attaché, with the rank of lieutenant commander. He took a deep interest in naval affairs, and presented papers on electrical-naval topics before various bodies connected with the Navy. He was also a valuable contributor to the proceedings of the American Institute of Electrical Engineers and to those of the New York Electrical Society. An important work to which he had of late devoted attention and energy is the standardization of electrical apparatus and its testing, etc.

The funeral took place at Schnectady on January 11th, and was attended by Governor Roosevelt and staff and officers of the National Guard, as well as by numerous mourners from all over the country.

GEO. A. BARNARD.

Mr. Geo. A. Barnard, member, died in New York, February 8, 1899, after a brief illness, aged 58 years. He was born in Albany, N. Y., and served during the civil war in both the Army and the Navy. He held an exceptionally high position in the mechanical commercial world, and did much to elevate the interests of mechanical engineering, especially in connection with stationary machinery.

He was a charter member of the American Society of Mechanical Engineers and an interested member of our own Society, and had a wide engineering experience.

At the time of his death he was the eastern representative of the Buckeye Engine Co., of Salem, Ohio.

Mr. Barnard leaves a wife, a son and a daughter.

CHARLES P. HOWELL.

Commander Charles P. Howell, U. S. N., died at his home in New York City, December 7, 1899, about 5 P. M., from heart failure. He had been ill but a few days before his death, and was at his desk at the Inspection Board, Navy Yard, New York, the day before. Commander Howell was born in Goshen, N. Y.,

January 18, 1848, and was appointed a Cadet Engineer October 7, 1867, from New York. He graduated from the Naval Academy June, 1868; was appointed Assistant Engineer August 15, 1870; Passed Assistant Engineer, December 3, 1876; Chief Engineer, November 10, 1893; Commissioned Lieutenant Commander, March 3, 1899, and Commander, July 8, 1899.

He served on the U. S. S. *Contoocook*, North Atlantic Station, from October, 1868, until January, 1870; U. S. S. *Tallapoosa*, 1870 until 1872; at Navy Department, 1872 until May, 1873; U. S. S. *Alaska*, European Station, August, 1873, to September, 1876; at New York Navy Yard, September, 1877, until November, 1878; U. S. S. *Tuscarora*, Pacific Station, November, 1878, until June, 1880; U. S. S. *Ranger*, Pacific Station, June, 1880, until June, 1882; U. S. S. *Alert*, Asiatic Station, October, 1883, until September, 1886; U. S. S. *Minnesota*, New York, July, 1887, to May, 1889. He was Inspector of Merchant Vessels at New York, June, 1889, to January, 1890; U. S. S. *Baltimore*, January, 1890, until June, 1892; U. S. S. *Ranger*, June, 1892, to May, 1893; New York Navy Yard, May, 1893, to December, 1895, after which he was assigned to duty on the U. S. S. *Maine*, where he was Chief Engineer when that ship was blown up in Havana Harbor on February 15, 1898. He was on the sick list for some time after that event, but during the Spanish-American war he was assigned on the U. S. S. *Newark*, which was refitted at the Norfolk Navy Yard. When the *Newark* put back to that port after a short trip, he left her to go again on the sick list, and saw no more active service during the Spanish-American war. He was assigned to duty in the navy yard at Havana a year ago, and remained there during the winter, after which he was assigned to duty at the New York Navy Yard, on July 2, 1899, where he remained until the time of his death.

He resided with his family at No. 126 East Thirty-fourth street, New York City. He leaves a widow, but no children. The interment was in Goshen, N. Y., where his mother and brothers reside. Commander Howell was highly esteemed by all with whom he ever came into contact. He was of exceptional ability and possessed a ripe experience in his profession.

ASSOCIATION NOTES.

The regular annual business meeting of the Society was held at the Navy Department on the evening of January 9, 1900, with a fair attendance of resident members.

The meeting was called to order at 7·30 P. M., and the report of the Secretary-Treasurer for the past year presented as follows:

GENTLEMEN: In accordance with the By-Laws, I have the honor to submit the annual report of the financial condition of this Society for the year just completed, and in doing so it is a pleasure to state that, in spite of the many predictions that the Personnel Bill would result in a greatly decreased interest in such an association, the results of the year, as well as the outlook, prove the Society to be in a most flourishing condition.

There have been a number of withdrawals through disaffection, but an increase in the Associate list to more than make up for that loss, and there is no doubt but that we will gain considerably in the near future from former line officers, now more interested in engineering matters, as soon as their eligibility to membership is well known.

The volume of the JOURNAL for the year is the largest ever published before without decreasing the balance of money on hand, and is the largest JOURNAL but one ever issued by us, the exception being that of its immediate predecessor, Volume X, which was made purposely larger to reduce the balance and distribute a portion of the surplus in that way.

The following is the Statement for 1899, and has been audited and found to be correct:

RECEIPTS.

Balance from last accounts, January 7, 1899	$4,074.74
Annual dues	2,255.00
Subscriptions, sale of JOURNAL and reprints	362.60
Advertisements	1,607.89
Sale of society buttons	1.20
Interest	80.11
Total	$8,381.54

EXPENDITURES.

Publishing JOURNAL and reprints	$2,465.71
Printing index, lists, blanks, etc	173.45
Illustrations	284.51
Salary Secretary-Treasurer	900.00
Incidentals, postage, stationery, etc., etc	127.57
Balance on hand January 8, 1900	4,430.30
Total	$8,381.54

Respectfully submitted,
A. B. WILLITS, *Secretary-Treasurer.*

The voting slips received by mail were then counted, both those for the award to prize essayists for 1890 and those for election of officers for the Society for 1900, and the results announced as follows:

PRIZE ESSAYISTS, 1899.

First prize (gold medal, life membership, and cash prize of 75 dollars) was awarded to Prof. W. F. Durand for his article entitled "Electrical Propulsion for Torpedo Boats."

Second prize (life membership and 25 dollars cash prize) was awarded to B. C. Ball for his article entitled "Indicator Diagrams of Multiple-Expansion Engines."

Both of these articles appeared in the February, 1899, JOURNAL.

OFFICERS FOR 1900.

President, Commander Harrie Webster.

Secretary-Treasurer, Lieutenant Commander A. B. Willits.

Council.—Lieutenant Commander F. H. Bailey, Lieutenant R. S. Griffin, Lieutenant B. C. Bryan,

The meeting was then adjourned *sine die.*

Members are requested to call the attention of such former line officers of their acquaintance as are particularly interested in Engineering matters to the present By-Laws of this Society.

All line officers are now eligible to membership, and it is believed that the JOURNAL will be both of interest and value to at least those who anticipate closer study of steam machinery and duty in immediate connection with it.

Back numbers of the JOURNAL, in a complete set to date, can be secured by application to the Society, and at a price not considered exorbitant in view of the scarcity of the earlier volumes.

A circular slip is being prepared to call attention of the Society to the matter of the address of letters, as well as of checks, money orders, etc., intended for the Secretary-Treasurer. Some confusion in the delivery of mail has resulted from the fact that the Navy Mutual Aid Association, also in the Navy Department, is addressed by a prefix title of Secretary-Treasurer. All matter sent to this Society, however, should be addressed without such prefix, and simply made out to "American Society of Naval Engineers, Navy Department, Washington, D. C."

The following announcements have been received and are self-explanatory:

"THE INSTITUTION OF CIVIL ENGINEERS.
Established 1818. Incorporated by Royal Charter 1828.
GREAT GEORGE STREET, WESTMINSTER, S. W.

January 31, 1900.

"AMERICAN SOCIETY OF NAVAL ENGINEERS,
"NAVY DEPARTMENT,
"Washington, D. C., U. S. A.

"Dear Sirs: I am instructed by the Council to inform you that they have fixed the Annual Conversazione of this Institution for Thursday, the 5th of July, when they will desire to extend a very cordial invitation to those members of your Society who may be in London then, as well as to the ladies of their families, to

attend that entertainment. This Conversazione, which leads to, perhaps, the largest annual gathering of Engineers from all parts of the country, is, on this particular occasion, to be held, by the kind permission of the Corporation of the City of London, in the rooms of their ancient Guildhall, and the President and Council desire to take this early opportunity of expressing a hope that they may, in due course, receive the names of any members of your Society, whether traveling in an organized party or individually, to whom official invitations may be issued to attend that function.

"I am, yours faithfully,

"J. H. T. TUDSBERY, *Secretary.*"

"UNITED STATES COMMISSION TO THE PARIS EXPOSITION OF 1900.

"ALBANY, N. Y., *December 20, 1899.*

"EDITOR JOURNAL OF AMERICAN

"SOCIETY OF NAVAL ENGINEERS,

"Washington, D. C.

"Dear Sir: I enclose herewith an official press notice of the International Congress of Life Saving and First Aid, held under the auspices of the Universal Exposition in Paris in 1900. Will you kindly give the matter such notice in your publication as in your opinion will interest your readers?

"Should further information be received on this Congress, or any other congress allied thereto, I shall take great pleasure in forwarding you the earliest information.

"Very respectfully,

"HOWARD J. ROGERS,

"*Director Education and Social Economy.*"

CONGRESS ON LIFE SAVING AND FIRST AID.

The Congress of Life Saving and First Aid will study the means of life saving and the placing of such means in operation under all conditions on land and sea, in case of fire, and in water, in time of peace or in time of war. This work will comprise papers, discussions and experiments.

The Congress appeals to societies of life saving at sea, navigation companies, voluntary fire companies, voluntary life-saving societies, societies of marines, ambulance, stretcher bearers, Red Cross societies, and aid to the wounded in time of war.

The Commission desires that these societies send not only delegates, but works and notices showing their operation, the services rendered, and that they shall take part in the meetings and experiments.

One may become a donor member to the Congress by sending his application blank and subscription of 20 francs to M. Felicien Michotte, General Secretary, 21 Rue Condercet, Paris.

This Congress will open on the 17th of July, and will last eight days.

The members will find all information at the Secretary's office for their stay in Paris.